FIG. 1

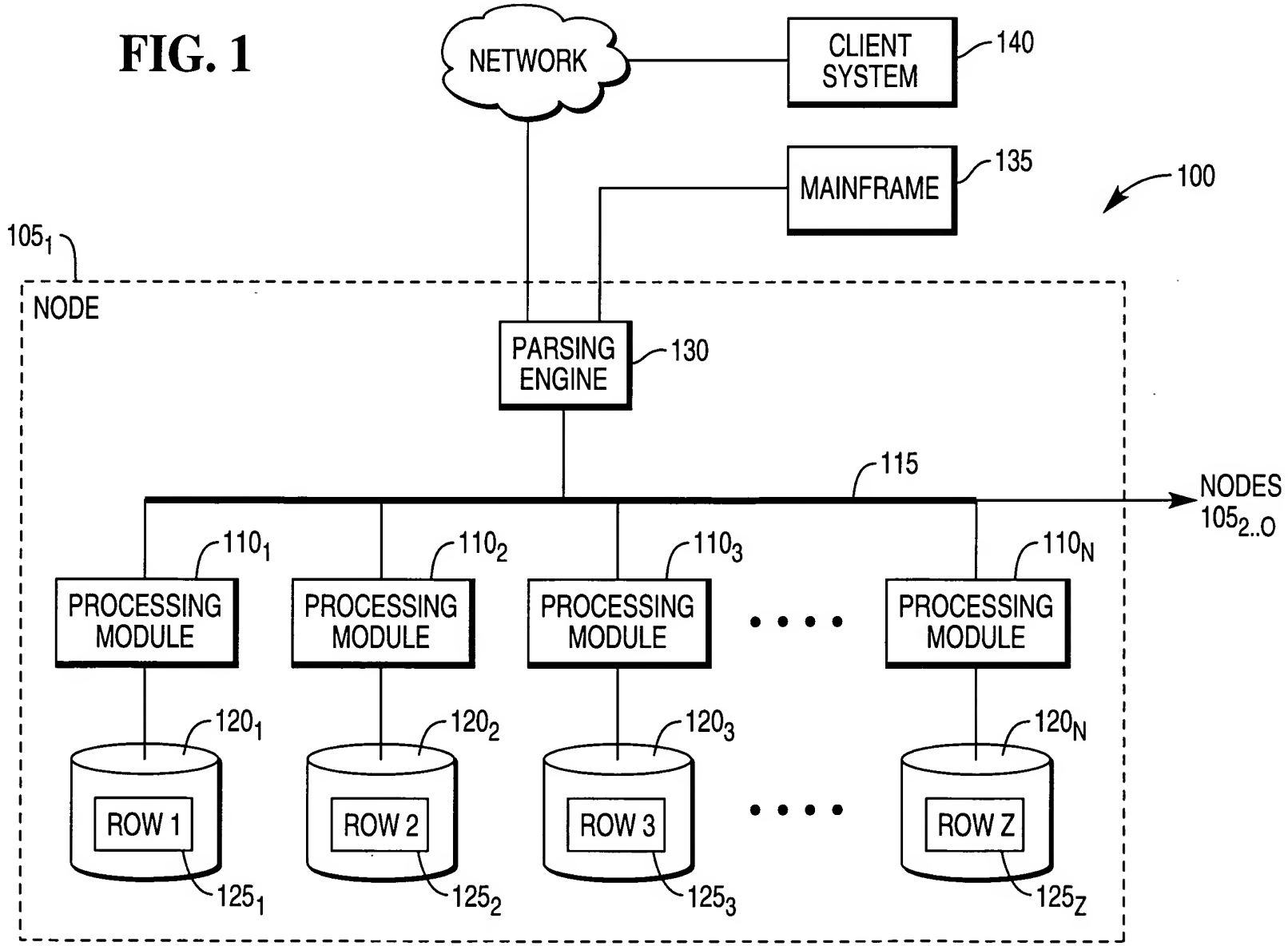


FIG. 2

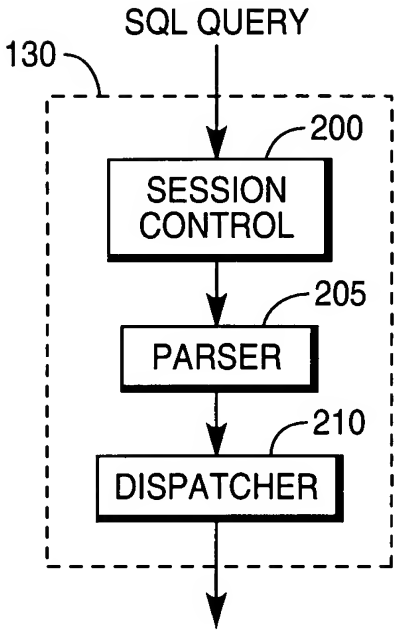

SQL QUERY
130
200
SESSION CONTROL
205
PARSER
210
DISPATCHER

FIG. 3

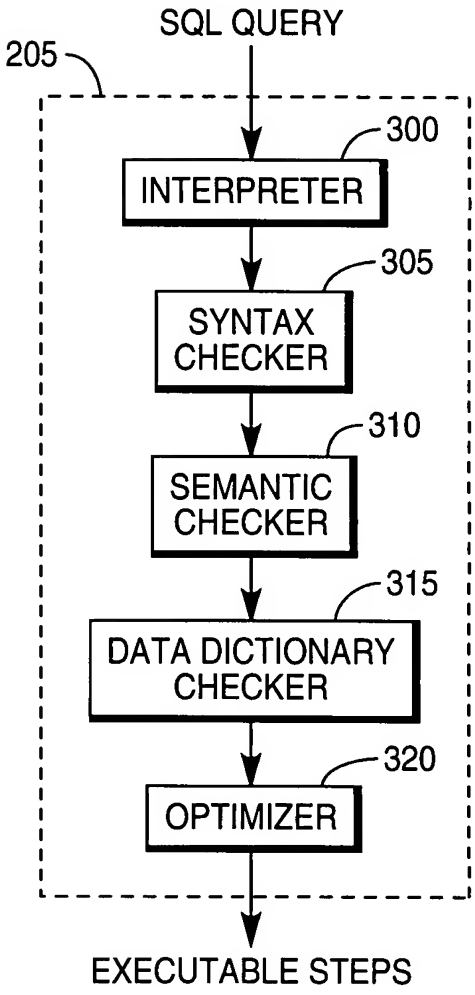
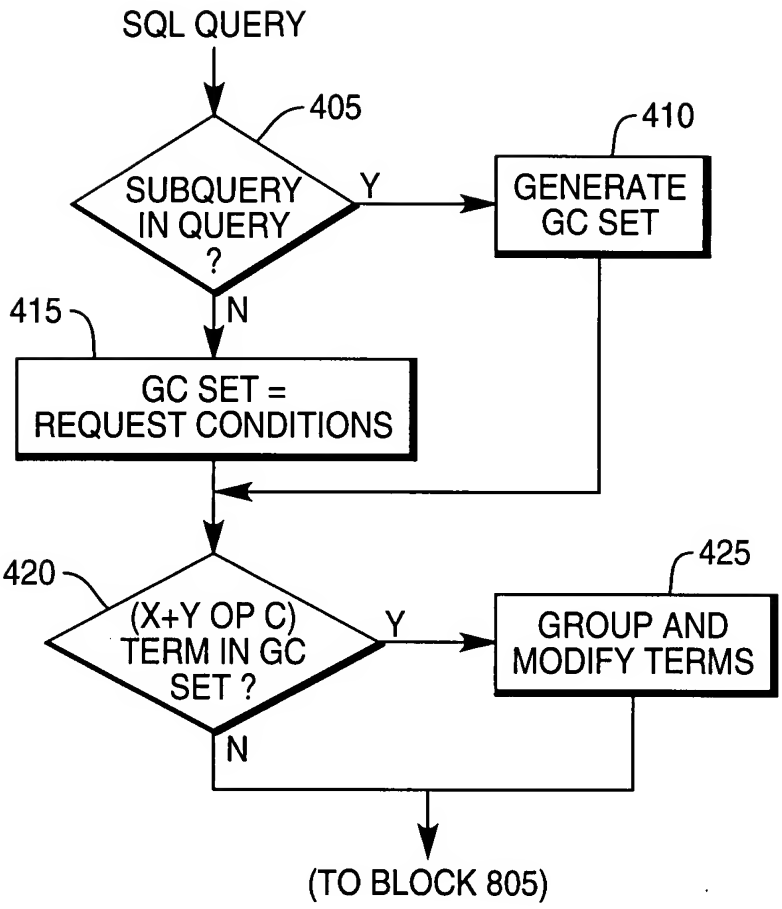

SQL QUERY
205
300
INTERPRETER
305
SYNTAX CHECKER
310
SEMANTIC CHECKER
315
DATA DICTIONARY CHECKER
320
OPTIMIZER
EXECUTABLE STEPS

FIG. 4


SQL QUERY
405
SUBQUERY IN QUERY ?
Y
410
GENERATE GC SET
N
415
GC SET = REQUEST CONDITIONS
420
(X+Y OP C) TERM IN GC SET ?
Y
425
GROUP AND MODIFY TERMS
N
(TO BLOCK 805)

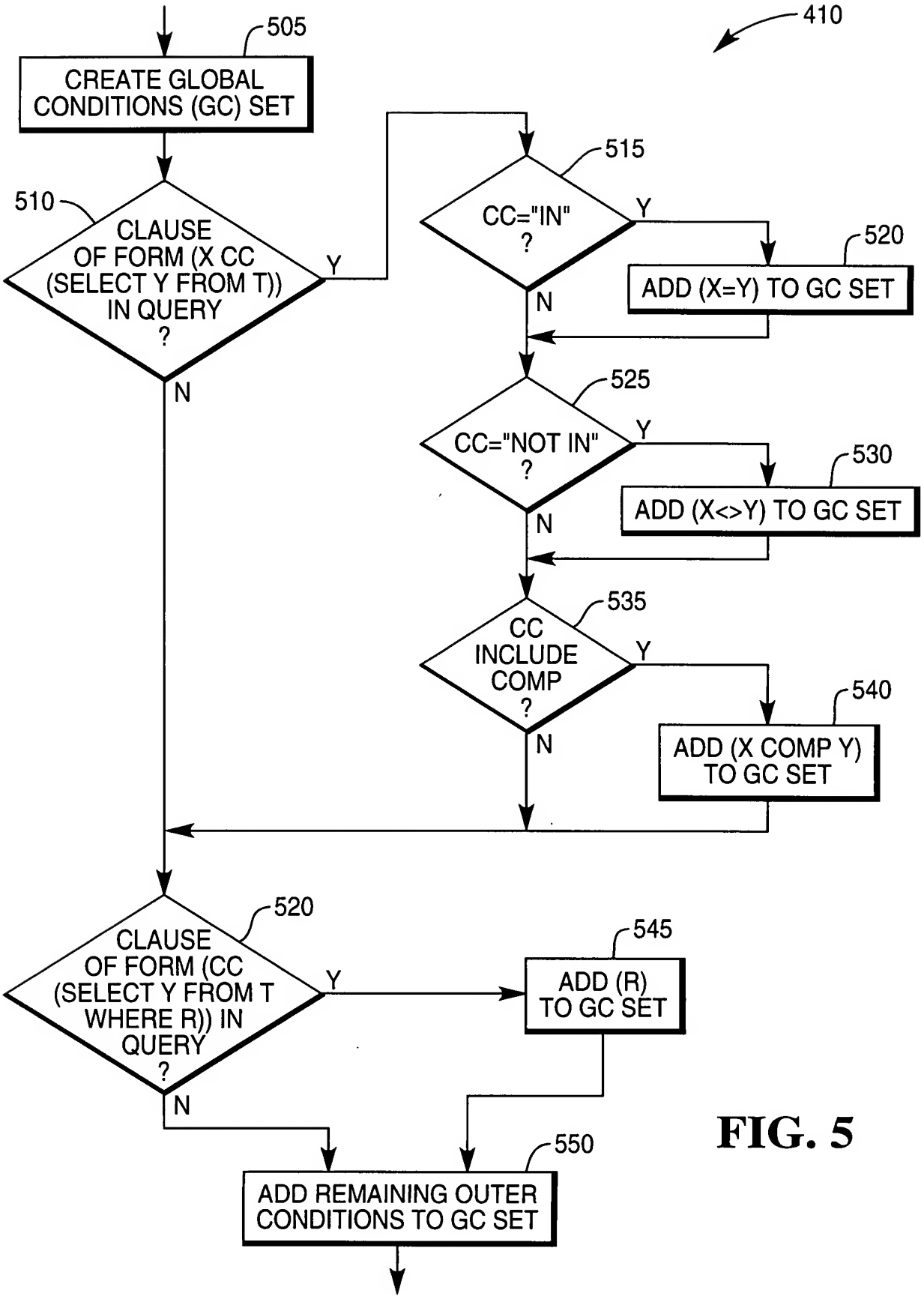

410
505
CREATE GLOBAL CONDITIONS (GC) SET
510
CLAUSE OF FORM (X CC (SELECT Y FROM T)) IN QUERY ?
Y
N
515
CC="IN" ?
Y
N
520
ADD (X=Y) TO GC SET
525
CC="NOT IN" ?
Y
N
530
ADD (X<>Y) TO GC SET
535
CC INCLUDE COMP ?
Y
N
540
ADD (X COMP Y) TO GC SET
520
CLAUSE OF FORM (CC (SELECT Y FROM T WHERE R)) IN QUERY ?
Y
N
545
ADD (R) TO GC SET
550
ADD REMAINING OUTER CONDITIONS TO GC SET

FIG. 5

FIG. 6

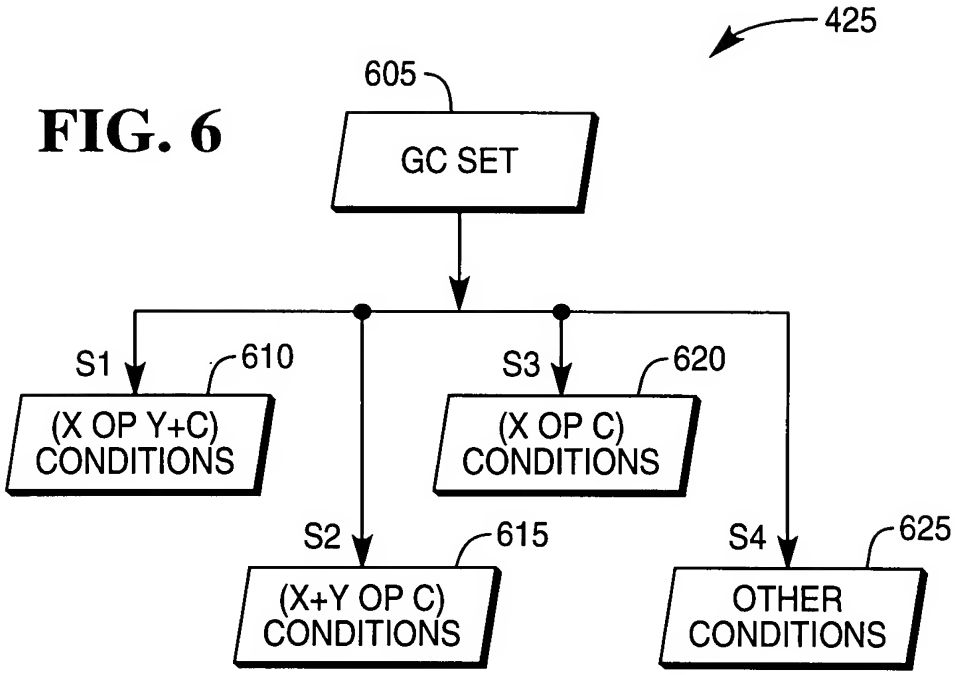

425
605
GC SET
S1
610
(X OP Y+C) CONDITIONS
S3
620
(X OP C) CONDITIONS
S2
615
(X+Y OP C) CONDITIONS
S4
625
OTHER CONDITIONS

FIG. 7

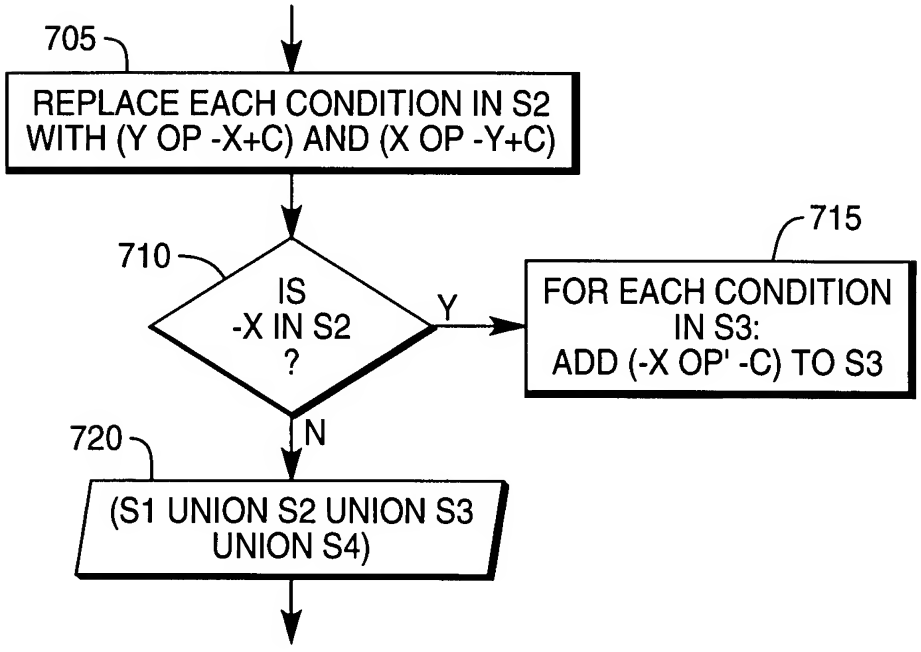

705
REPLACE EACH CONDITION IN S2 WITH (Y OP -X+C) AND (X OP -Y+C)
710
IS -X IN S2 ?
Y
715
FOR EACH CONDITION IN S3: ADD (-X OP' -C) TO S3
N
720
(S1 UNION S2 UNION S3 UNION S4)

FIG. 8

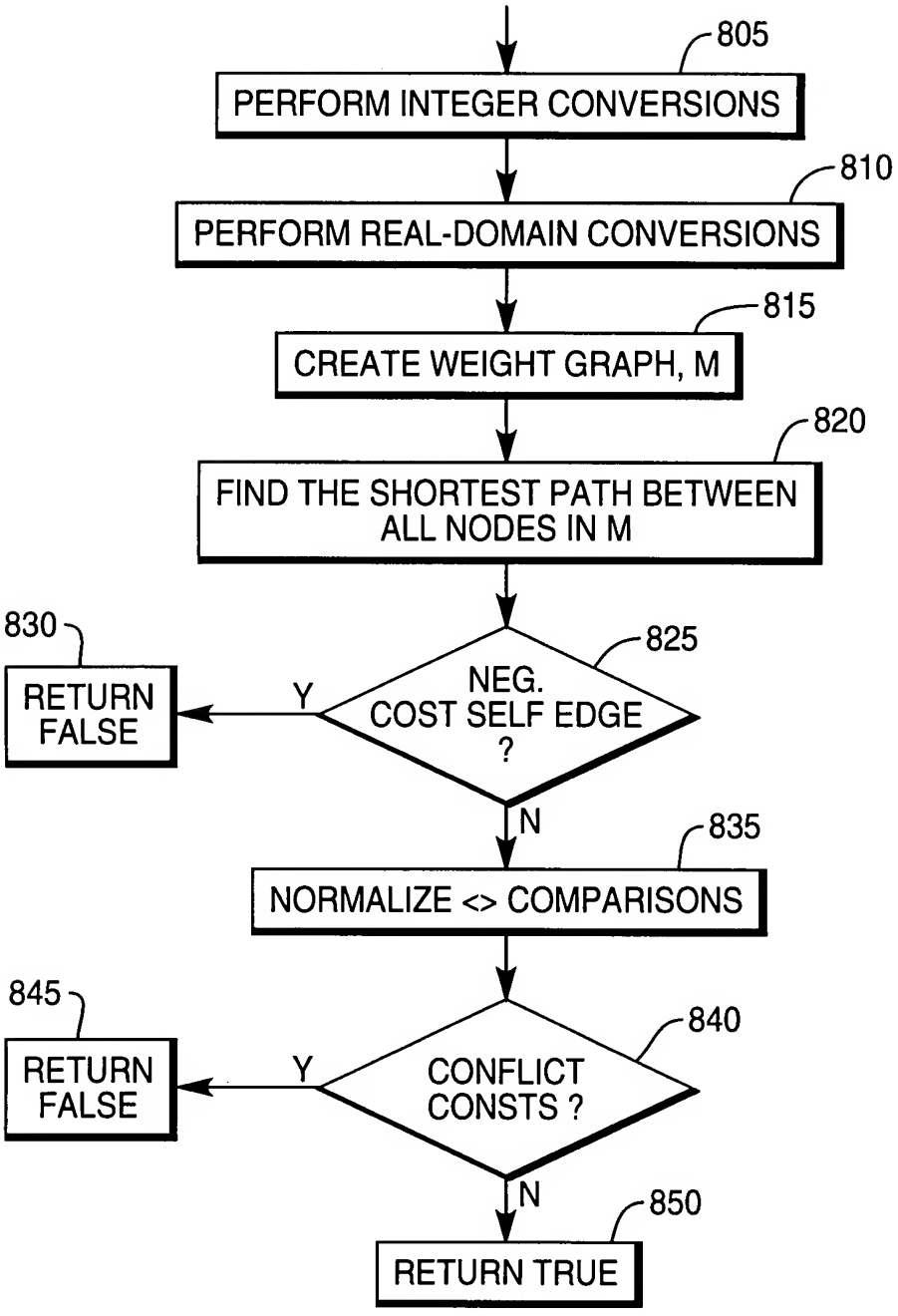

805
PERFORM INTEGER CONVERSIONS
810
PERFORM REAL-DOMAIN CONVERSIONS
815
CREATE WEIGHT GRAPH, M
820
FIND THE SHORTEST PATH BETWEEN ALL NODES IN M
825
NEG. COST SELF EDGE ?
Y
830
RETURN FALSE
N
835
NORMALIZE <> COMPARISONS
840
CONFLICT CONSTS ?
Y
845
RETURN FALSE
N
850
RETURN TRUE

FIG. 9

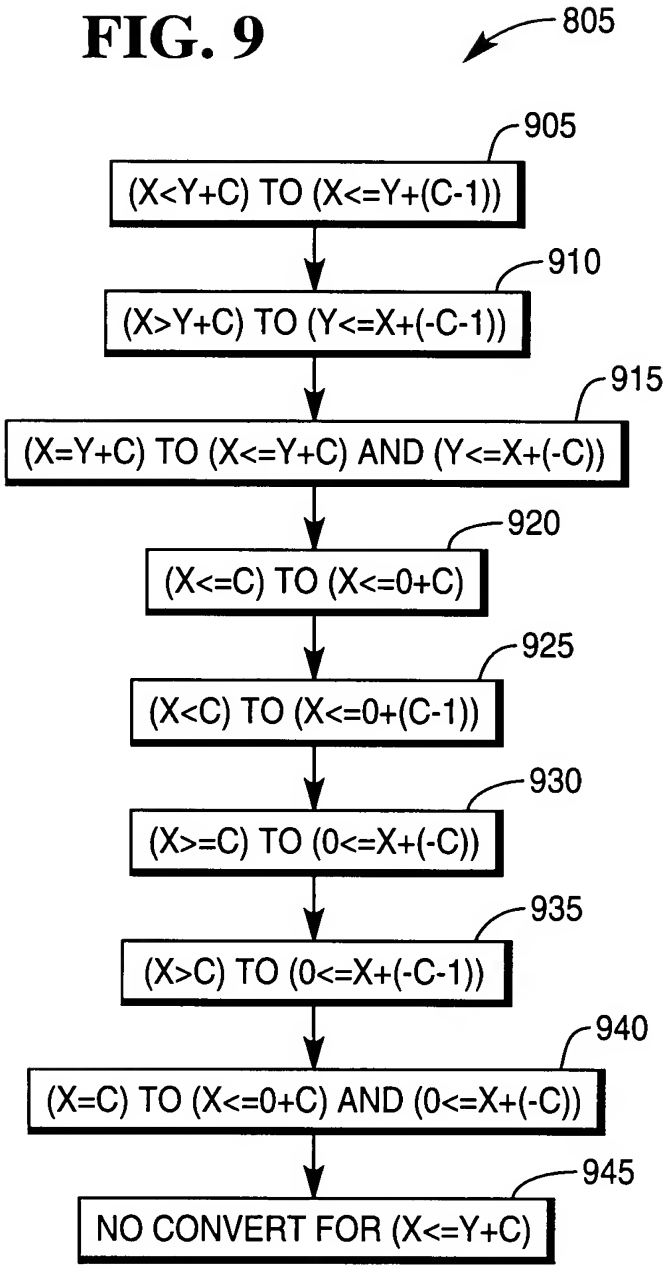

805
905
(X<Y+C) TO (X<=Y+(C-1))
910
(X>Y+C) TO (Y<=X+(-C-1))
915
(X=Y+C) TO (X<=Y+C) AND (Y<=X+(-C))
920
(X<=C) TO (X<=0+C)
925
(X<C) TO (X<=0+(C-1))
930
(X>=C) TO (0<=X+(-C))
935
(X>C) TO (0<=X+(-C-1))
940
(X=C) TO (X<=0+C) AND (0<=X+(-C))
945
NO CONVERT FOR (X<=Y+C)

FIG. 10

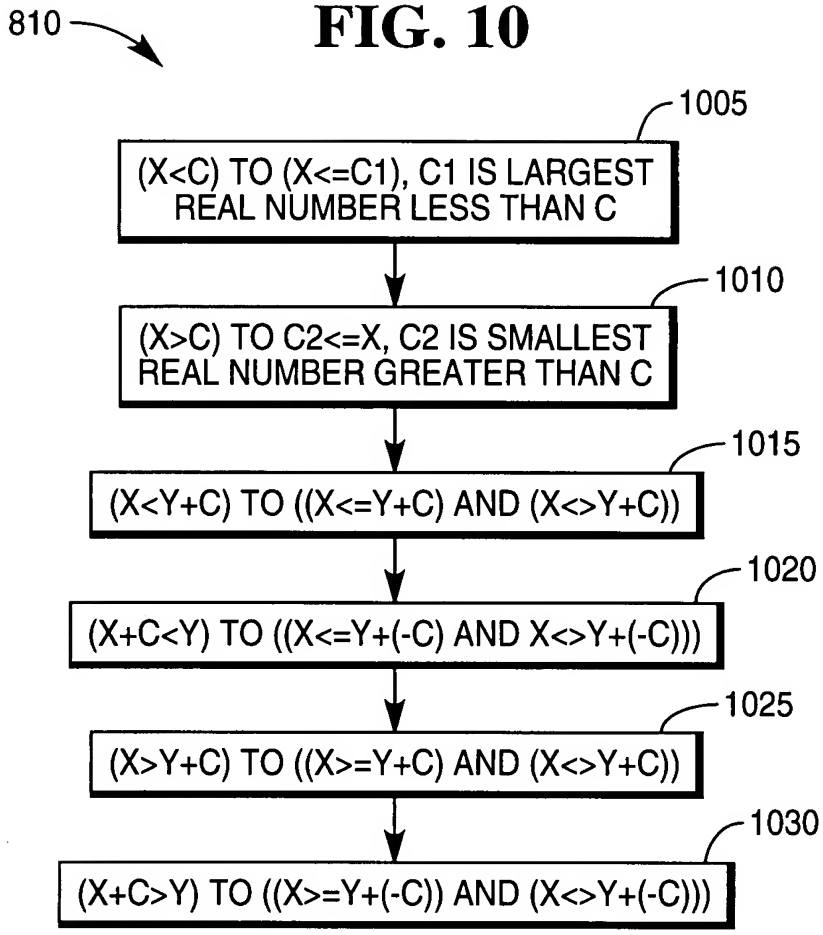

810
1005
(X<C) TO (X<=C1), C1 IS LARGEST REAL NUMBER LESS THAN C
1010
(X>C) TO C2<=X, C2 IS SMALLEST REAL NUMBER GREATER THAN C
1015
(X<Y+C) TO ((X<=Y+C) AND (X<>Y+C))
1020
(X+C<Y) TO ((X<=Y+(-C) AND X<>Y+(-C)))
1025
(X>Y+C) TO ((X>=Y+C) AND (X<>Y+C))
1030
(X+C>Y) TO ((X>=Y+(-C)) AND (X<>Y+(-C)))

FIG. 11

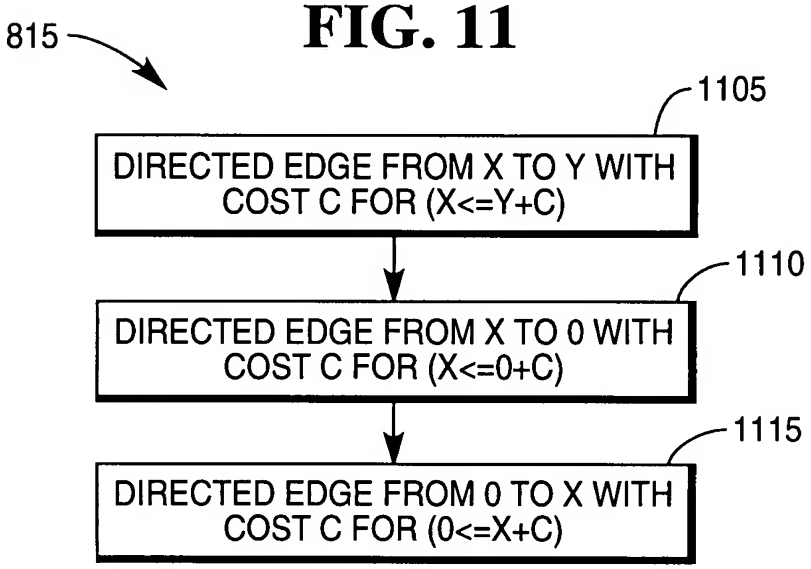
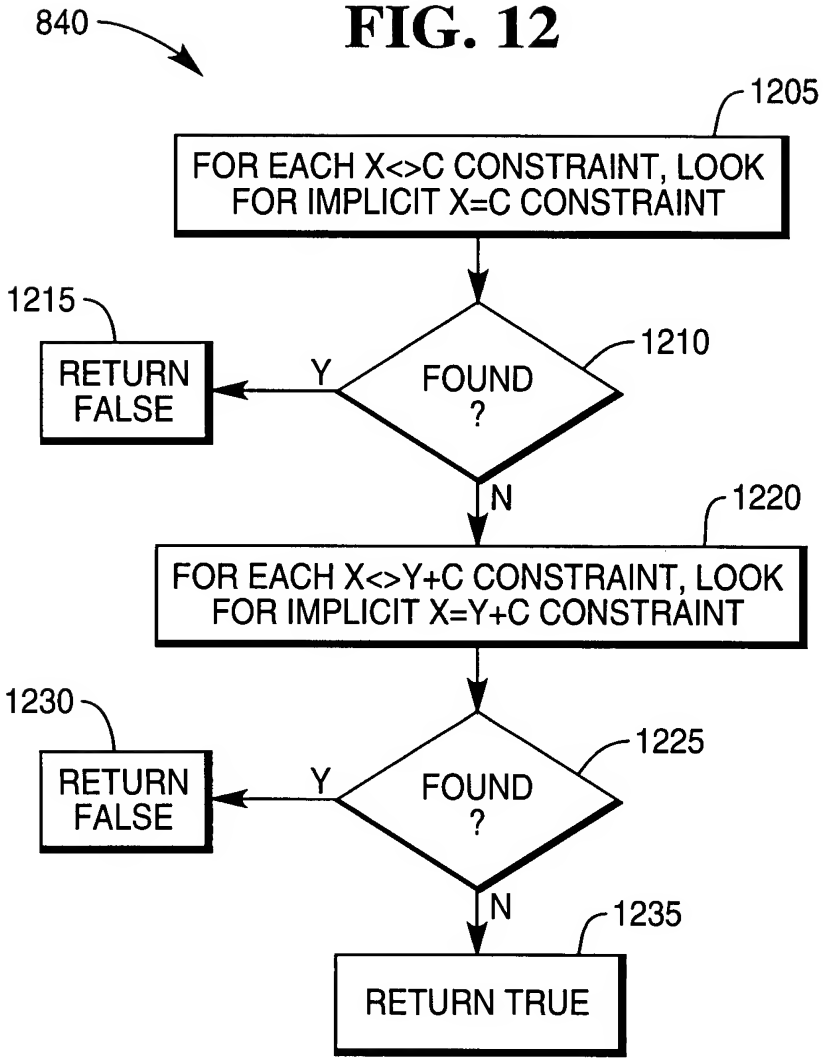

815
1105
DIRECTED EDGE FROM X TO Y WITH COST C FOR (X<=Y+C)
1110
DIRECTED EDGE FROM X TO 0 WITH COST C FOR (X<=0+C)
1115
DIRECTED EDGE FROM 0 TO X WITH COST C FOR (0<=X+C)

FIG. 12


840
1205
FOR EACH X<>C CONSTRAINT, LOOK FOR IMPLICIT X=C CONSTRAINT
1215
RETURN FALSE
Y
FOUND ?
1210
N
1220
FOR EACH X<>Y+C CONSTRAINT, LOOK FOR IMPLICIT X=Y+C CONSTRAINT
1230
RETURN FALSE
Y
FOUND ?
1225
N
1235
RETURN TRUE

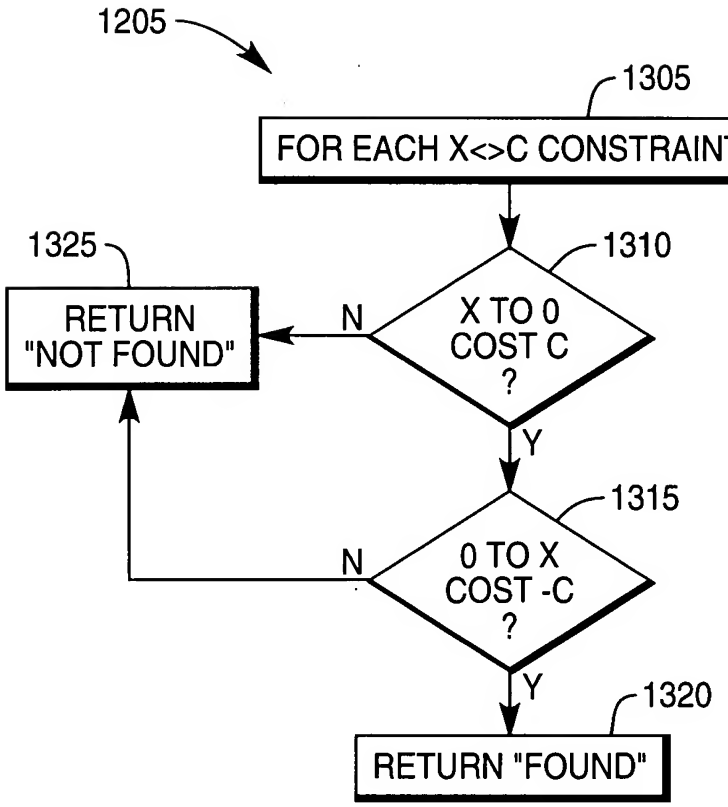

1205
1305
FOR EACH X<>C CONSTRAINT
1310
X TO 0
COST C
?
N
1325
RETURN
"NOT FOUND"
Y
1315
0 TO X
COST -C
?
N
Y
1320
RETURN "FOUND"

FIG. 13

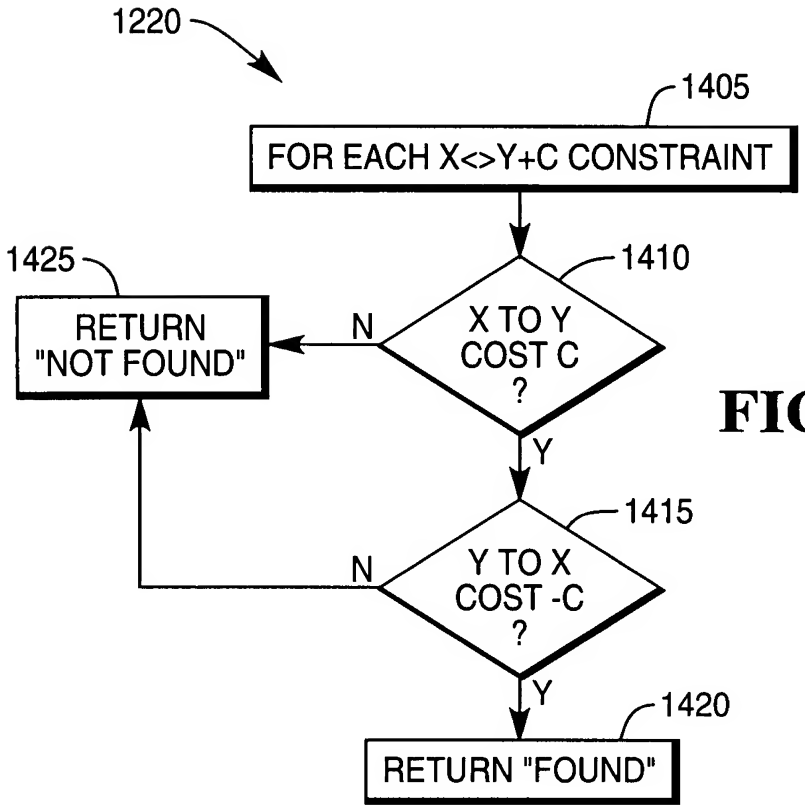

1220
1405
FOR EACH X<>Y+C CONSTRAINT
1410
X TO Y
COST C
?
N
1425
RETURN
"NOT FOUND"
Y
1415
Y TO X
COST -C
?
N
Y
1420
RETURN "FOUND"

FIG. 14

FIG. 15

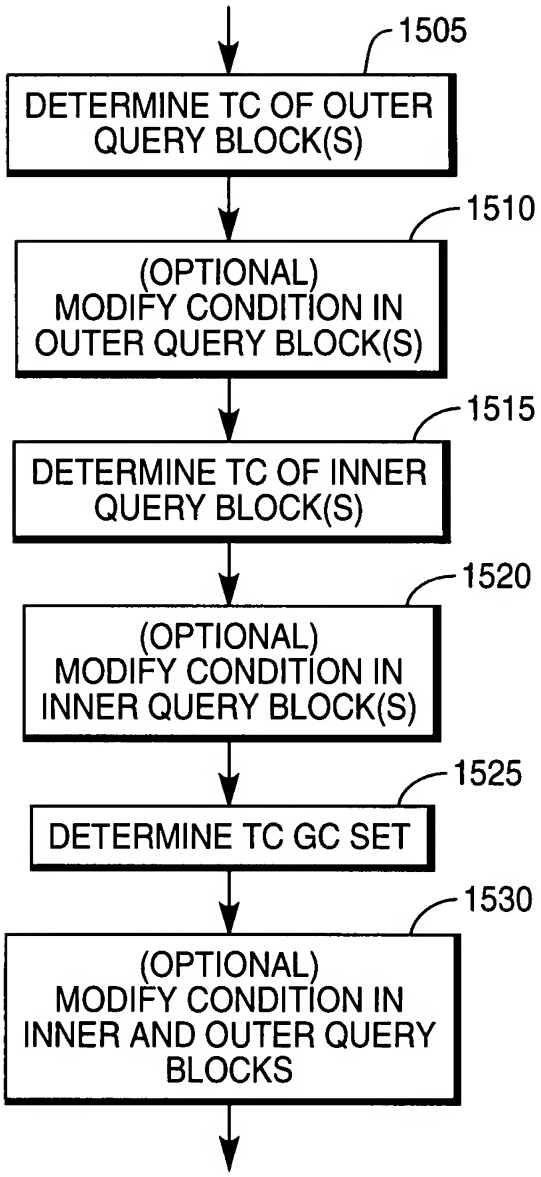
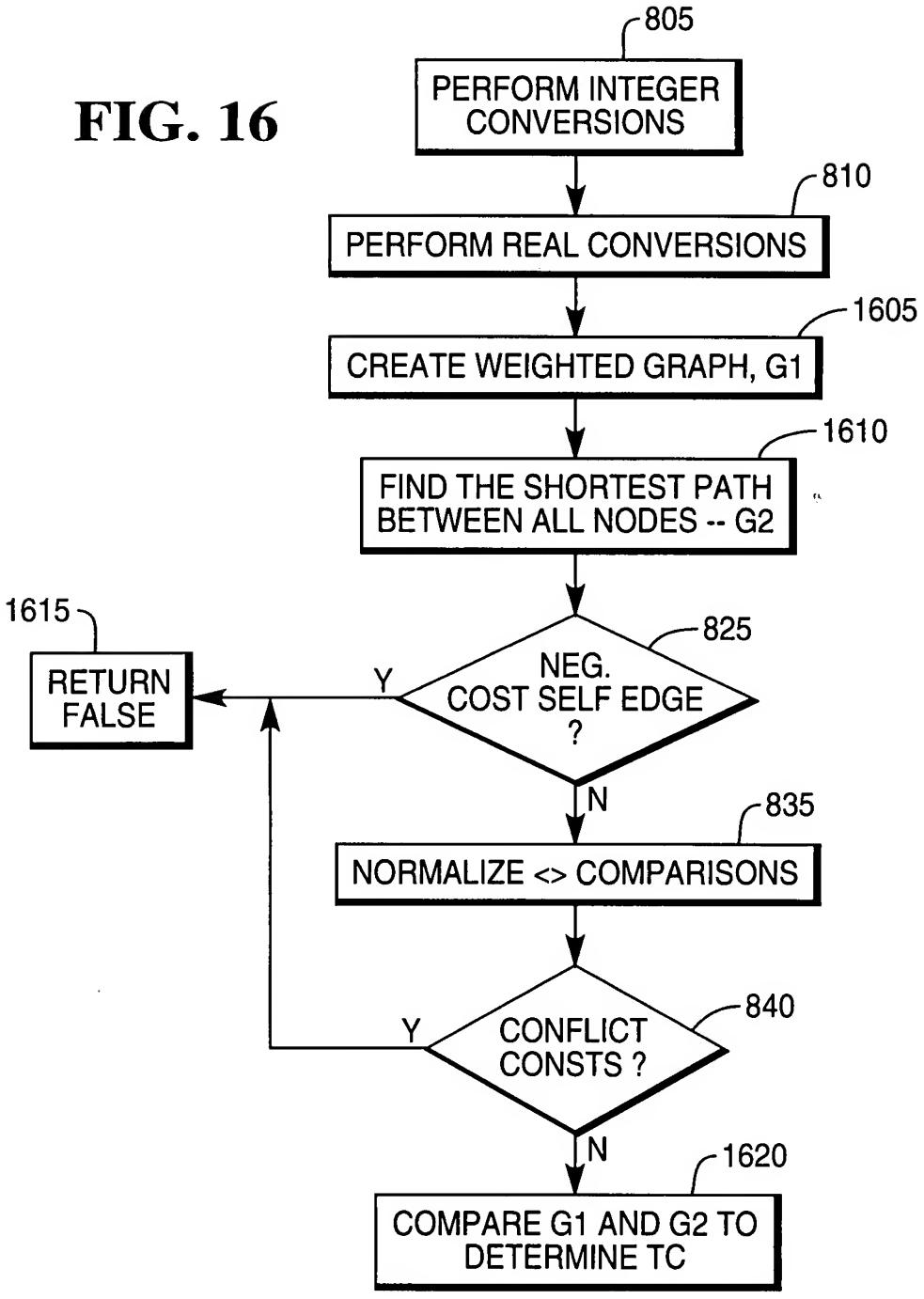

1505
DETERMINE TC OF OUTER QUERY BLOCK(S)
1510
(OPTIONAL) MODIFY CONDITION IN OUTER QUERY BLOCK(S)
1515
DETERMINE TC OF INNER QUERY BLOCK(S)
1520
(OPTIONAL) MODIFY CONDITION IN INNER QUERY BLOCK(S)
1525
DETERMINE TC GC SET
1530
(OPTIONAL) MODIFY CONDITION IN INNER AND OUTER QUERY BLOCKS

FIG. 16


805
PERFORM INTEGER CONVERSIONS
810
PERFORM REAL CONVERSIONS
1605
CREATE WEIGHTED GRAPH, G1
1610
FIND THE SHORTEST PATH BETWEEN ALL NODES -- G2
825
NEG. COST SELF EDGE ?
Y
1615
RETURN FALSE
N
835
NORMALIZE <> COMPARISONS
840
CONFLICT CONSTS ?
Y
N
1620
COMPARE G1 AND G2 TO DETERMINE TC

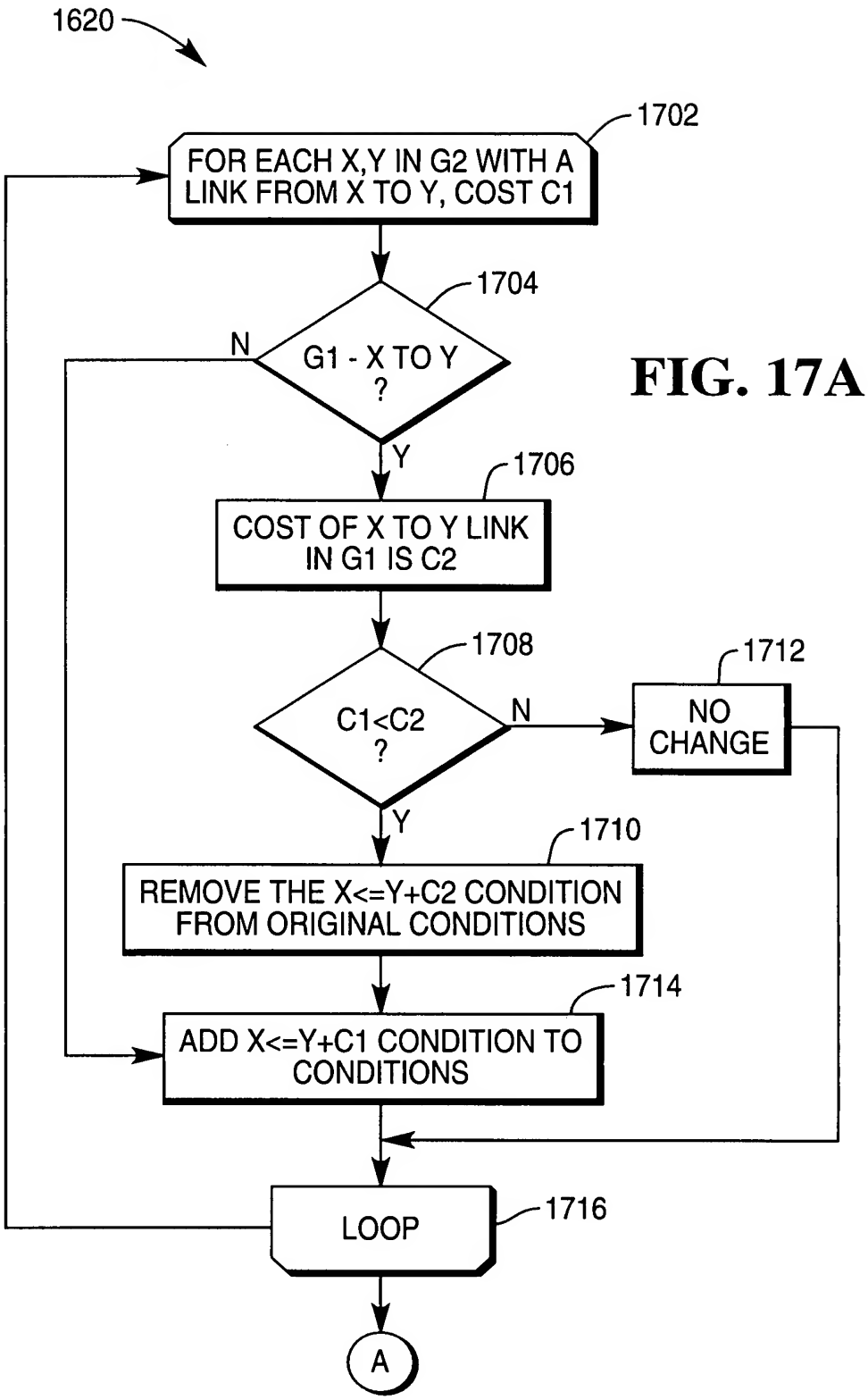

1620
1702
FOR EACH X,Y IN G2 WITH A LINK FROM X TO Y, COST C1
1704
G1 - X TO Y ?
N
Y
1706
COST OF X TO Y LINK IN G1 IS C2
1708
C1<C2 ?
N
1712
NO CHANGE
Y
1710
REMOVE THE X<=Y+C2 CONDITION FROM ORIGINAL CONDITIONS
1714
ADD X<=Y+C1 CONDITION TO CONDITIONS
LOOP
1716
A

FIG. 17A

FIG. 17B

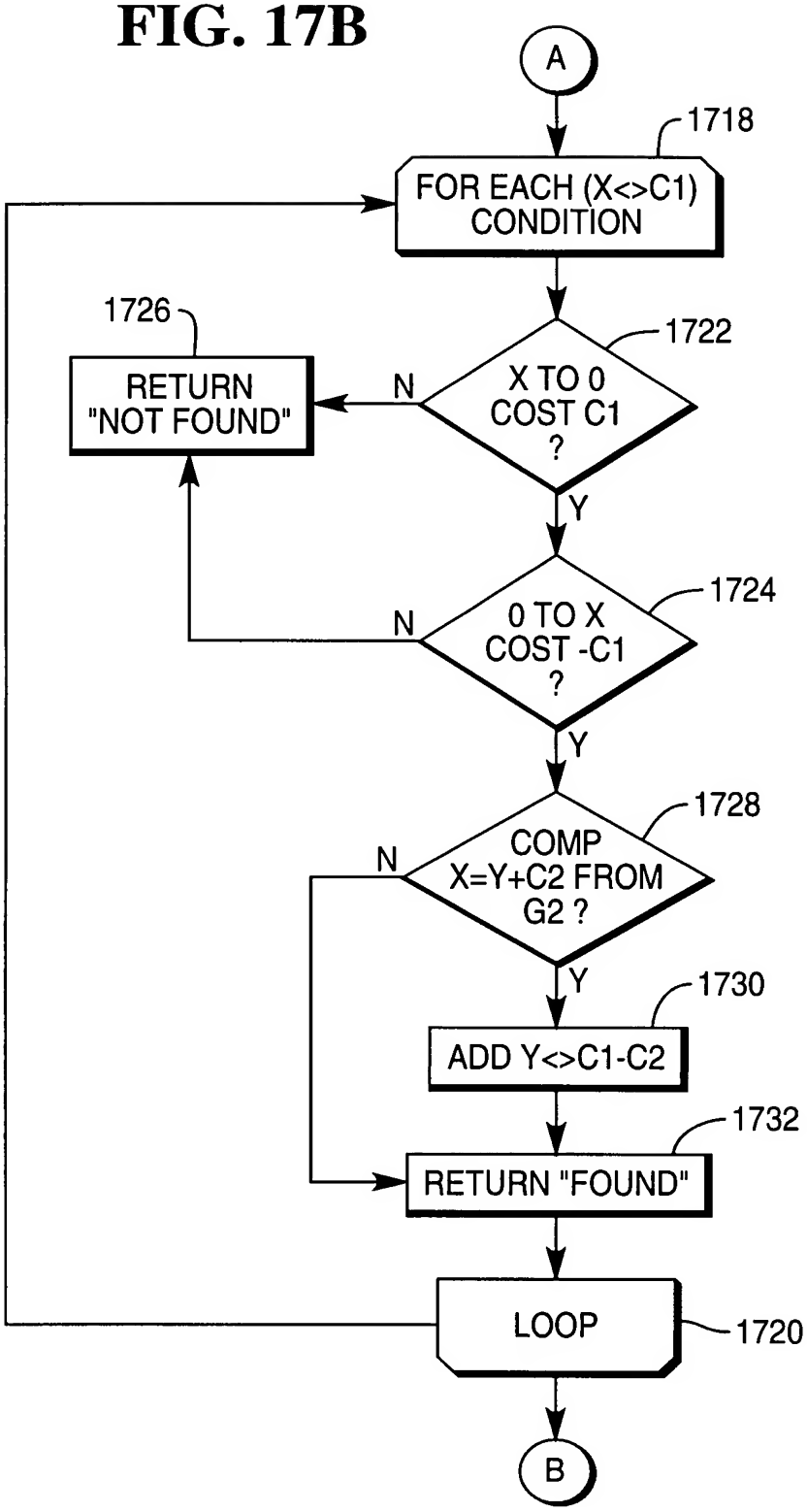
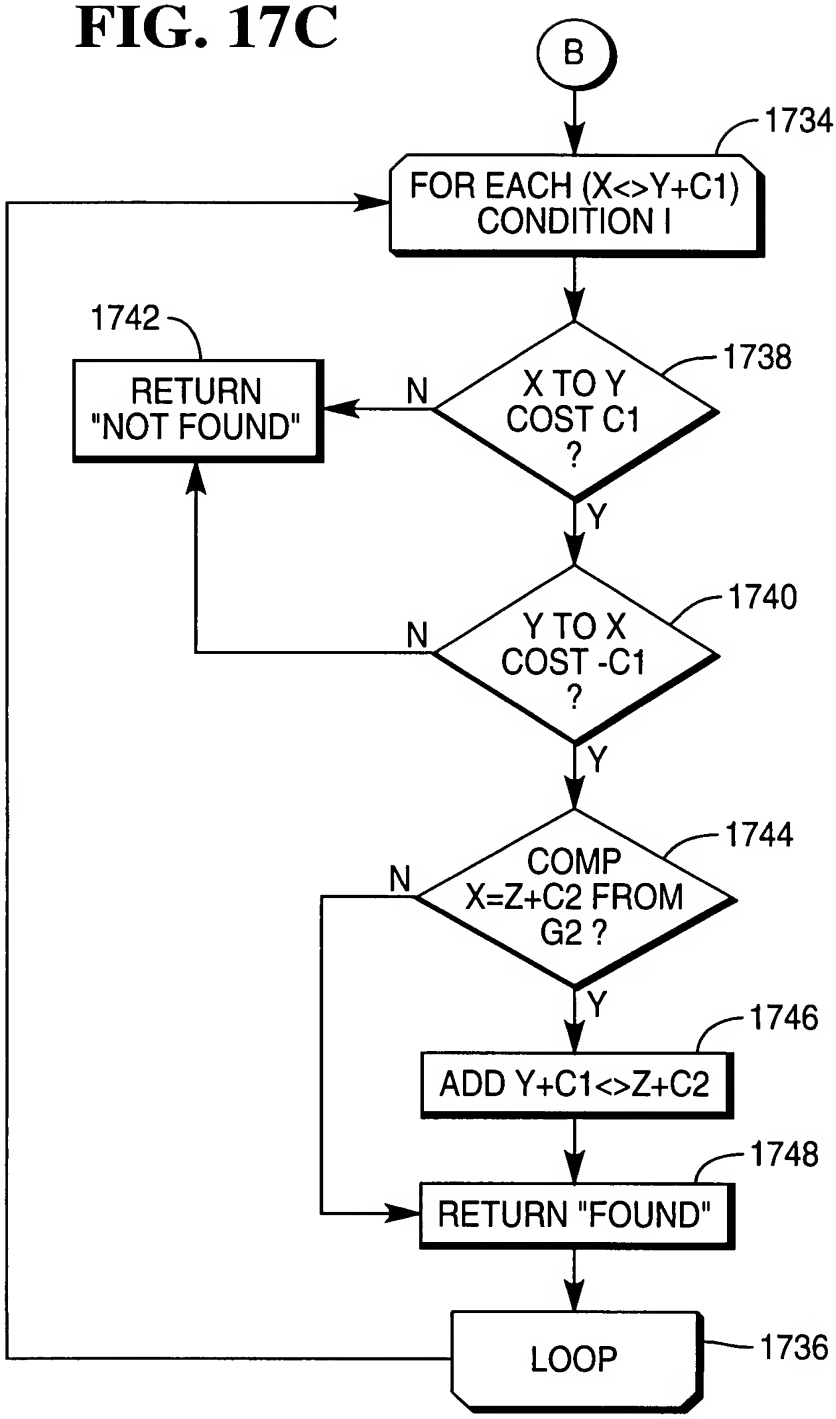

A
1718
FOR EACH (X<>C1) CONDITION
1726
RETURN "NOT FOUND"
N
1722
X TO 0 COST C1 ?
Y
1724
0 TO X COST -C1 ?
N
Y
1728
COMP X=Y+C2 FROM G2 ?
N
Y
1730
ADD Y<>C1-C2
1732
RETURN "FOUND"
LOOP
1720
B

FIG. 17C


B
1734
FOR EACH (X<>Y+C1)
CONDITION I
1738
X TO Y
COST C1
?
N
1742
RETURN
"NOT FOUND"
Y
1740
Y TO X
COST -C1
?
N
Y
1744
COMP
X=Z+C2 FROM
G2 ?
N
Y
1746
ADD Y+C1<>Z+C2
1748
RETURN "FOUND"
LOOP
1736

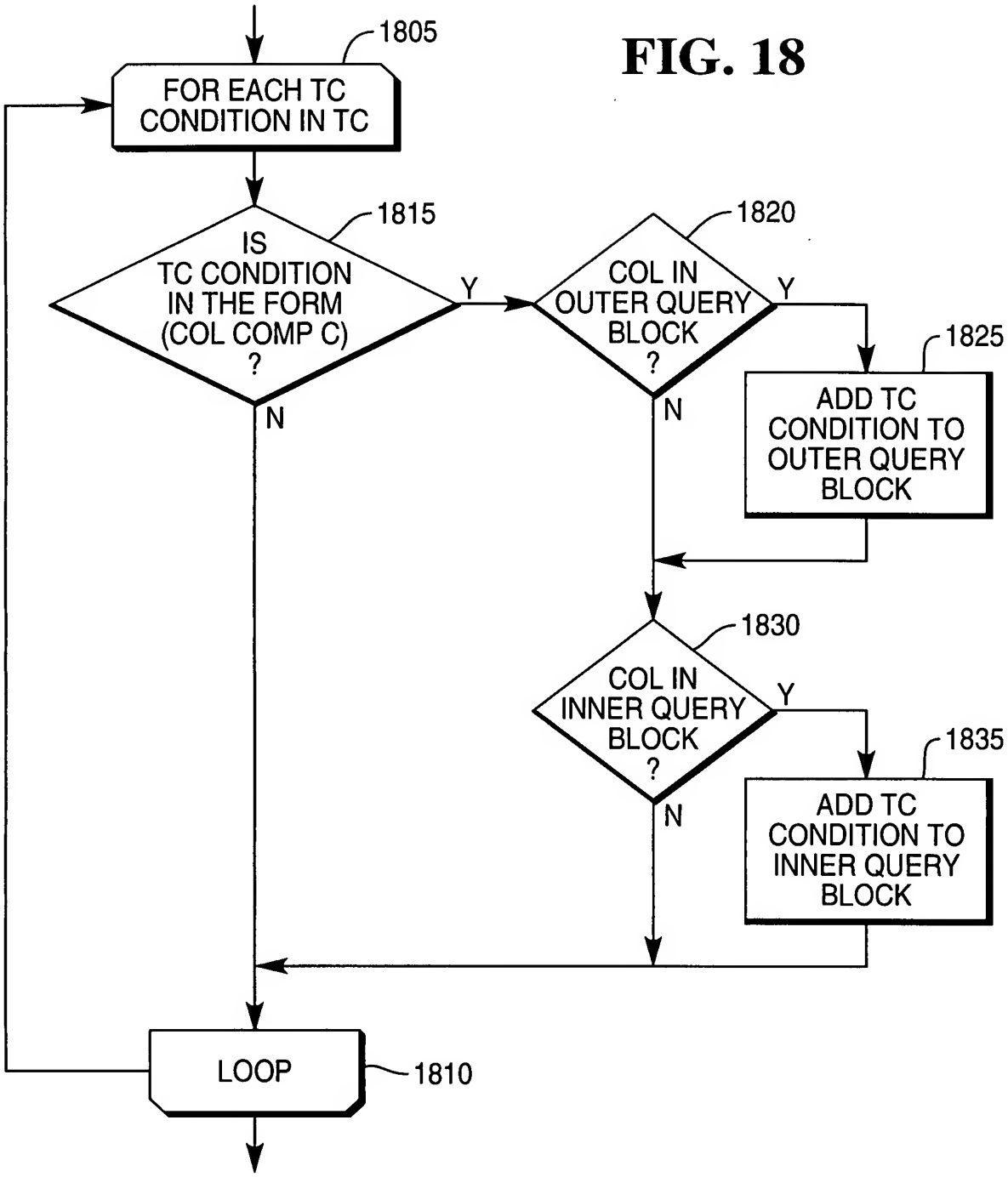

1805
FOR EACH TC CONDITION IN TC
1815
IS TC CONDITION IN THE FORM (COL COMP C) ?
Y
N
1820
COL IN OUTER QUERY BLOCK ?
Y
N
1825
ADD TC CONDITION TO OUTER QUERY BLOCK
1830
COL IN INNER QUERY BLOCK ?
Y
N
1835
ADD TC CONDITION TO INNER QUERY BLOCK
LOOP
1810

FIG. 18

FIG. 1

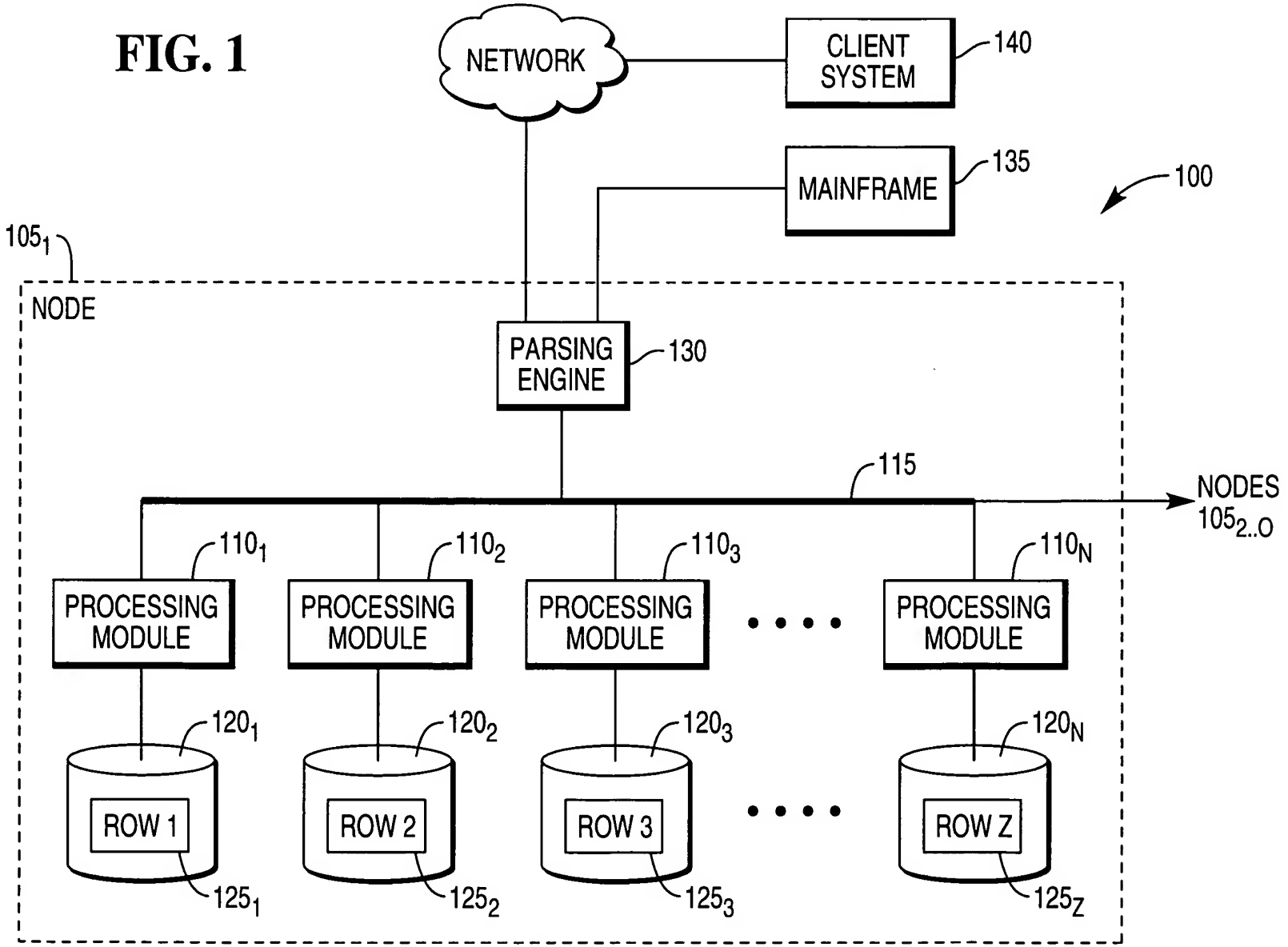

NETWORK
CLIENT SYSTEM
140
MAINFRAME
135
100
105_1
NODE
PARSING ENGINE
130
115
NODES $105_{2..O}$
110_1
110_2
110_3
110_N
PROCESSING MODULE
PROCESSING MODULE
PROCESSING MODULE
PROCESSING MODULE
120_1
120_2
120_3
120_N
ROW 1
ROW 2
ROW 3
ROW Z
125_1
125_2
125_3
125_Z

FIG. 2

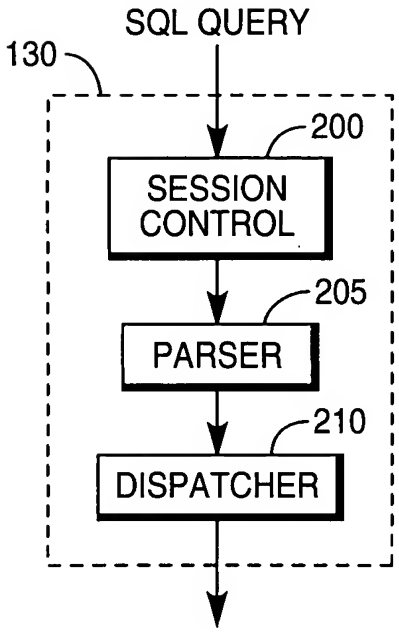

SQL QUERY
130
200
SESSION CONTROL
205
PARSER
210
DISPATCHER

FIG. 3

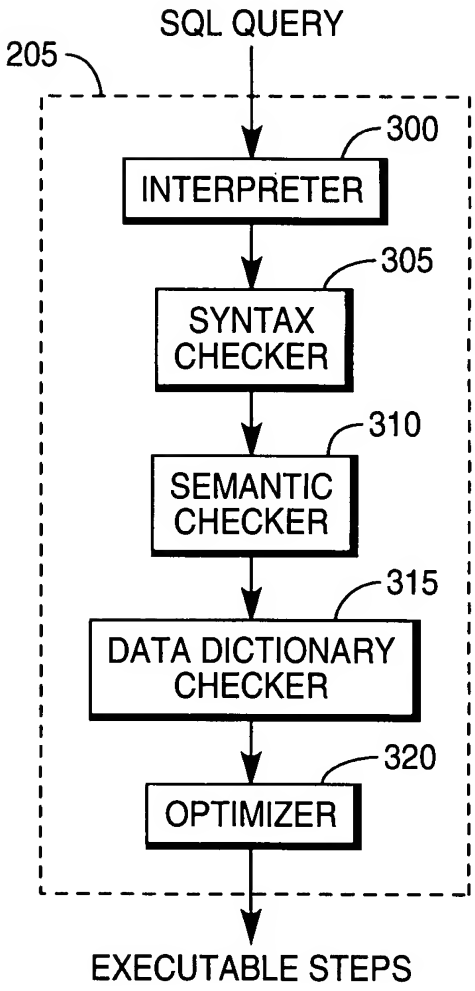
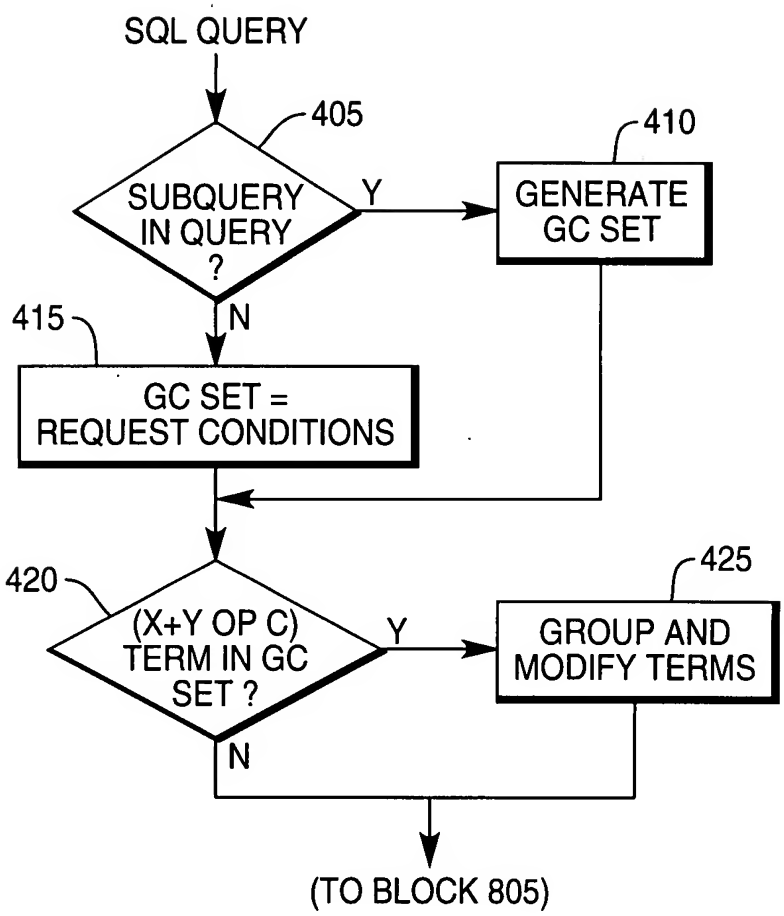

SQL QUERY
205
300
INTERPRETER
305
SYNTAX CHECKER
310
SEMANTIC CHECKER
315
DATA DICTIONARY CHECKER
320
OPTIMIZER
EXECUTABLE STEPS

FIG. 4


SQL QUERY
405
SUBQUERY IN QUERY ?
Y
410
GENERATE GC SET
N
415
GC SET = REQUEST CONDITIONS
420
(X+Y OP C) TERM IN GC SET ?
Y
425
GROUP AND MODIFY TERMS
N
(TO BLOCK 805)

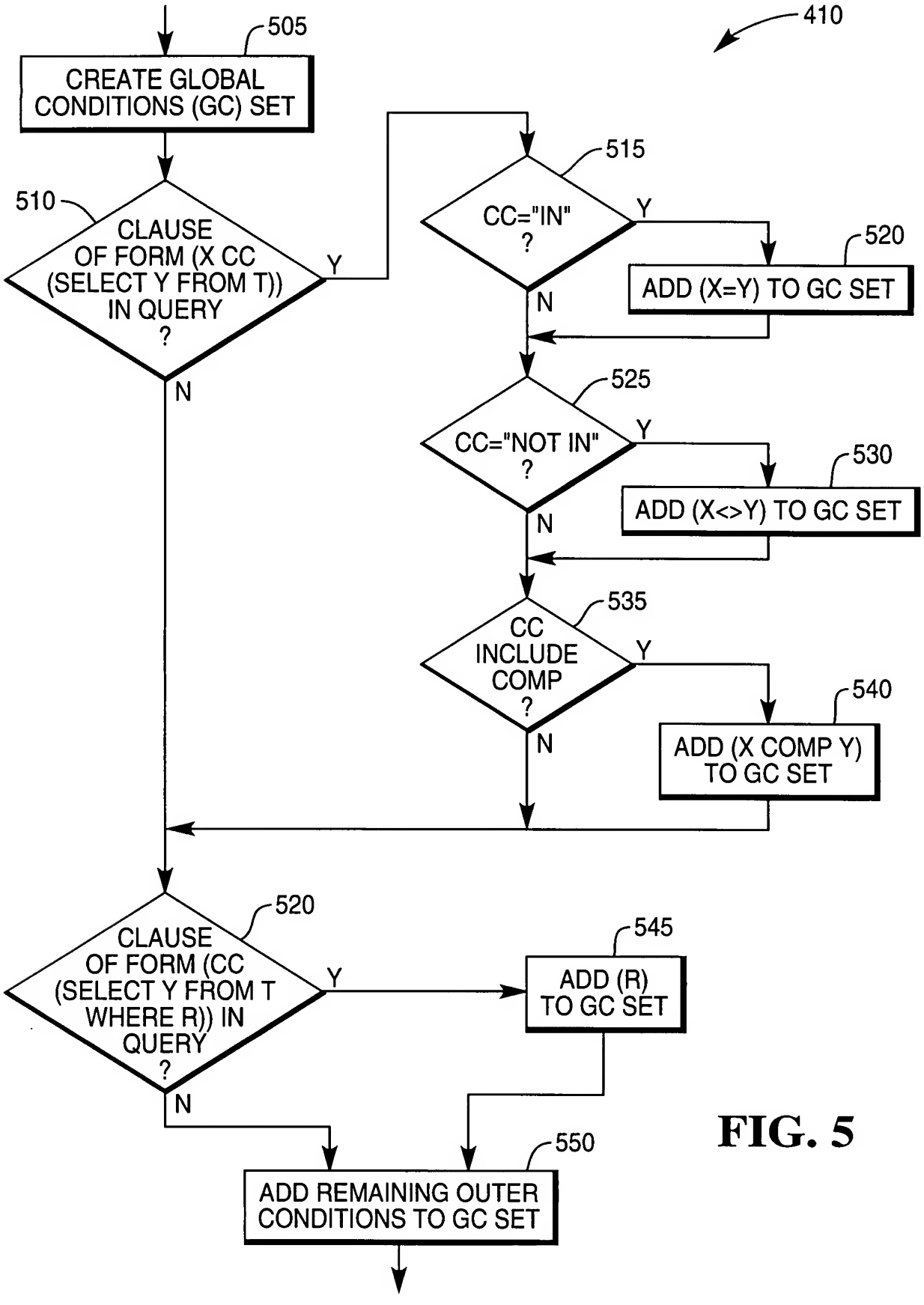

410
505
CREATE GLOBAL CONDITIONS (GC) SET
510
CLAUSE OF FORM (X CC (SELECT Y FROM T)) IN QUERY ?
Y
N
515
CC="IN" ?
Y
N
520
ADD (X=Y) TO GC SET
525
CC="NOT IN" ?
Y
N
530
ADD (X<>Y) TO GC SET
535
CC INCLUDE COMP ?
Y
N
540
ADD (X COMP Y) TO GC SET
520
CLAUSE OF FORM (CC (SELECT Y FROM T WHERE R)) IN QUERY ?
Y
N
545
ADD (R) TO GC SET
550
ADD REMAINING OUTER CONDITIONS TO GC SET

FIG. 5

FIG. 6

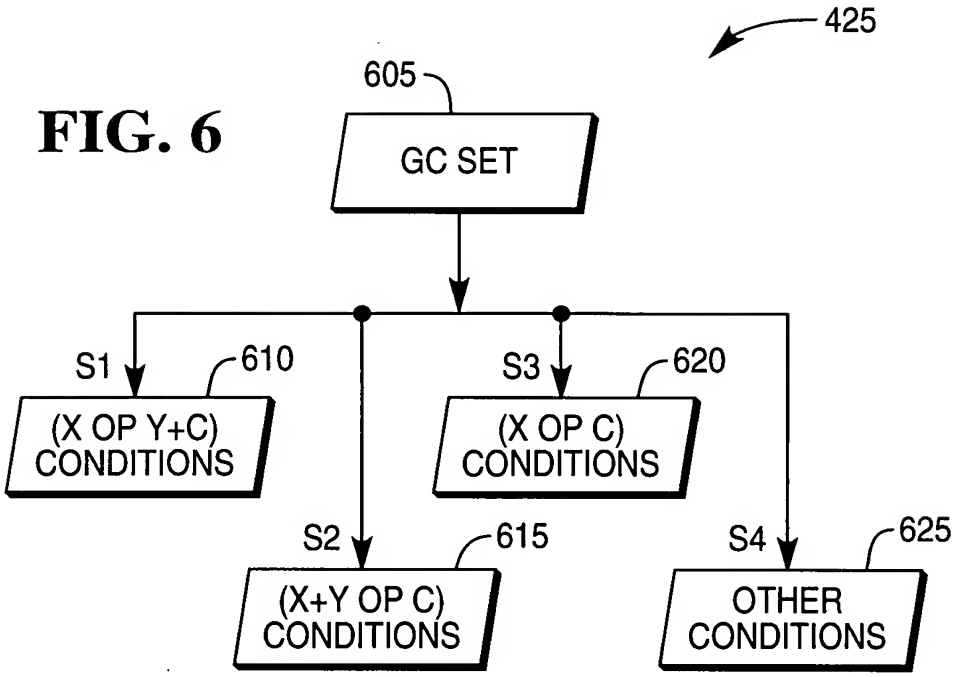

425
605
GC SET
S1
610
(X OP Y+C) CONDITIONS
S3
620
(X OP C) CONDITIONS
S2
615
(X+Y OP C) CONDITIONS
S4
625
OTHER CONDITIONS

FIG. 7

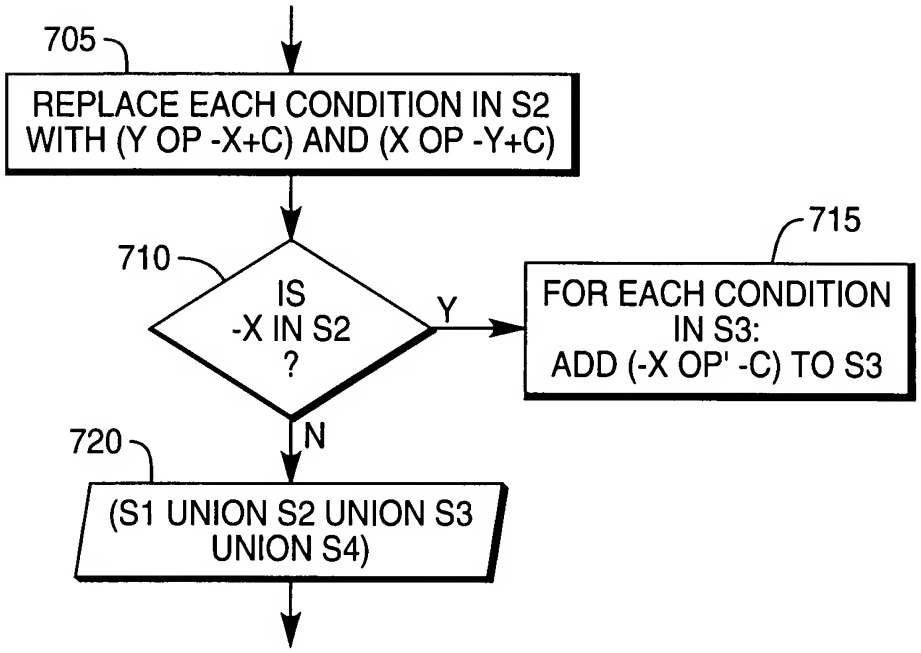

705
REPLACE EACH CONDITION IN S2 WITH (Y OP -X+C) AND (X OP -Y+C)
710
IS -X IN S2 ?
Y
715
FOR EACH CONDITION IN S3: ADD (-X OP' -C) TO S3
N
720
(S1 UNION S2 UNION S3 UNION S4)

FIG. 8

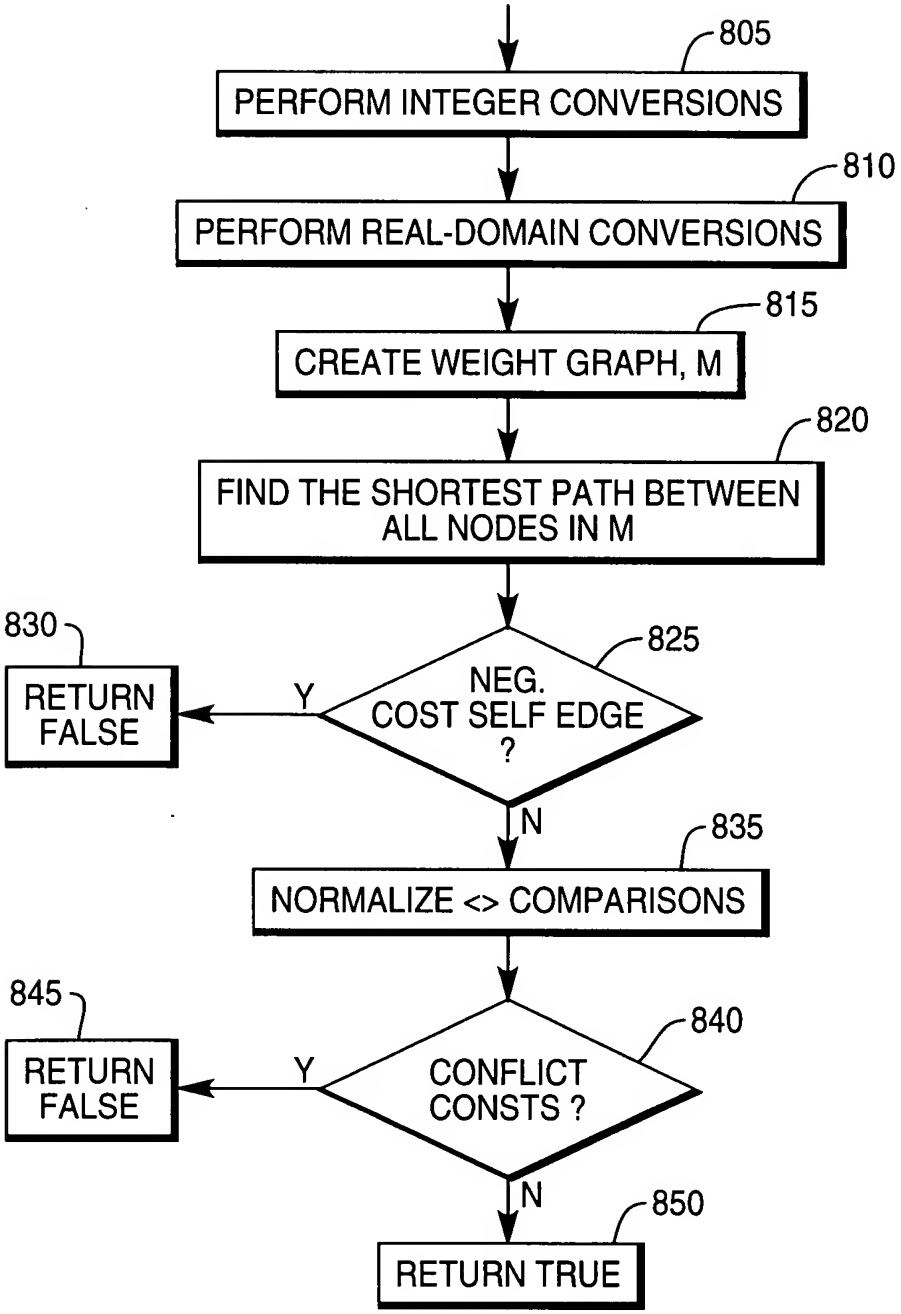
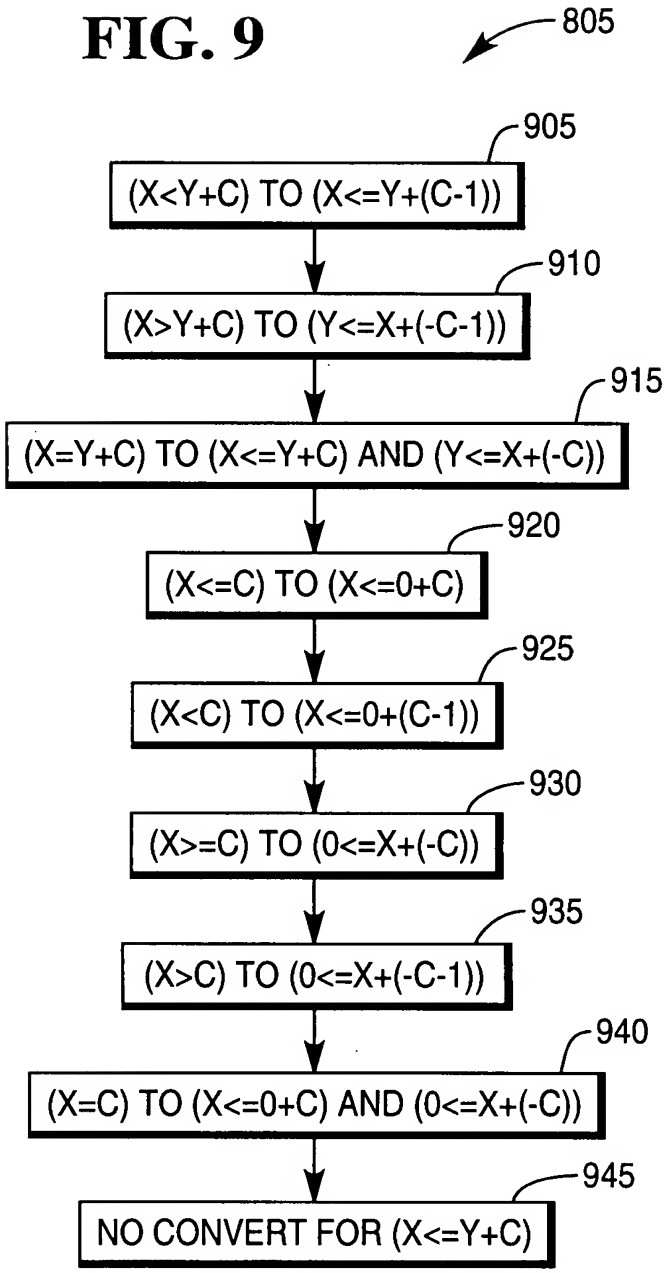

805
PERFORM INTEGER CONVERSIONS
810
PERFORM REAL-DOMAIN CONVERSIONS
815
CREATE WEIGHT GRAPH, M
820
FIND THE SHORTEST PATH BETWEEN ALL NODES IN M
825
NEG. COST SELF EDGE ?
Y
830
RETURN FALSE
N
835
NORMALIZE <> COMPARISONS
840
CONFLICT CONSTS ?
Y
845
RETURN FALSE
N
850
RETURN TRUE

FIG. 9


805
905
(X<Y+C) TO (X<=Y+(C-1))
910
(X>Y+C) TO (Y<=X+(-C-1))
915
(X=Y+C) TO (X<=Y+C) AND (Y<=X+(-C))
920
(X<=C) TO (X<=0+C)
925
(X<C) TO (X<=0+(C-1))
930
(X>=C) TO (0<=X+(-C))
935
(X>C) TO (0<=X+(-C-1))
940
(X=C) TO (X<=0+C) AND (0<=X+(-C))
945
NO CONVERT FOR (X<=Y+C)

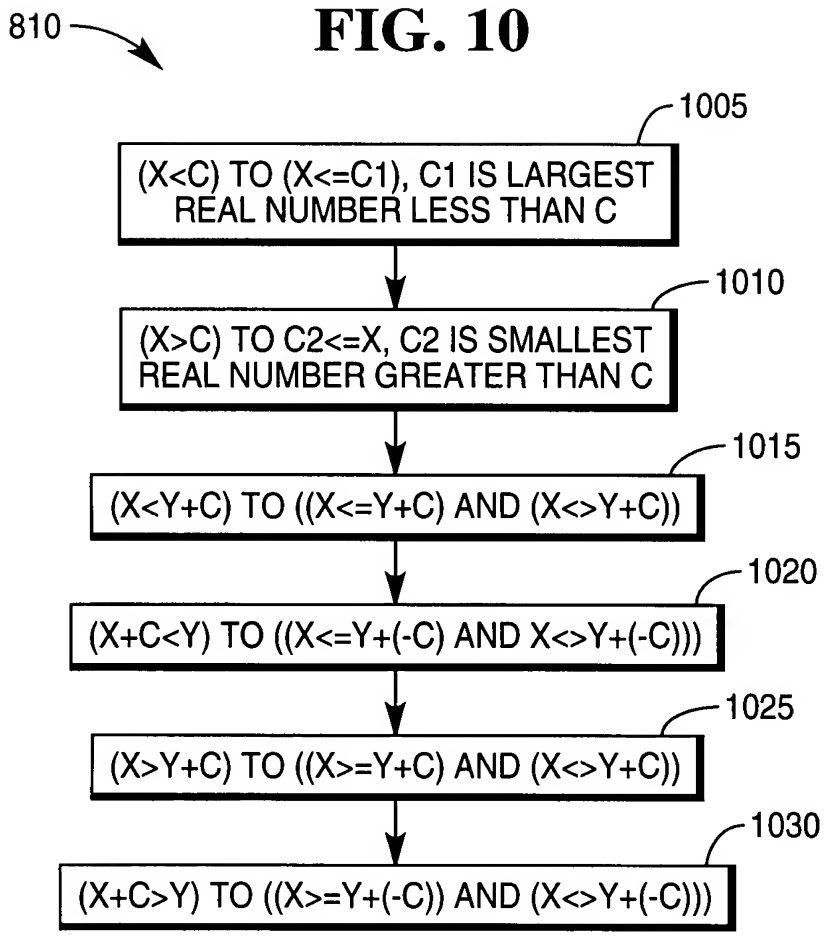

810
1005
(X<C) TO (X<=C1), C1 IS LARGEST REAL NUMBER LESS THAN C
1010
(X>C) TO C2<=X, C2 IS SMALLEST REAL NUMBER GREATER THAN C
1015
(X<Y+C) TO ((X<=Y+C) AND (X<>Y+C))
1020
(X+C<Y) TO ((X<=Y+(-C) AND X<>Y+(-C)))
1025
(X>Y+C) TO ((X>=Y+C) AND (X<>Y+C))
1030
(X+C>Y) TO ((X>=Y+(-C)) AND (X<>Y+(-C)))

FIG. 10

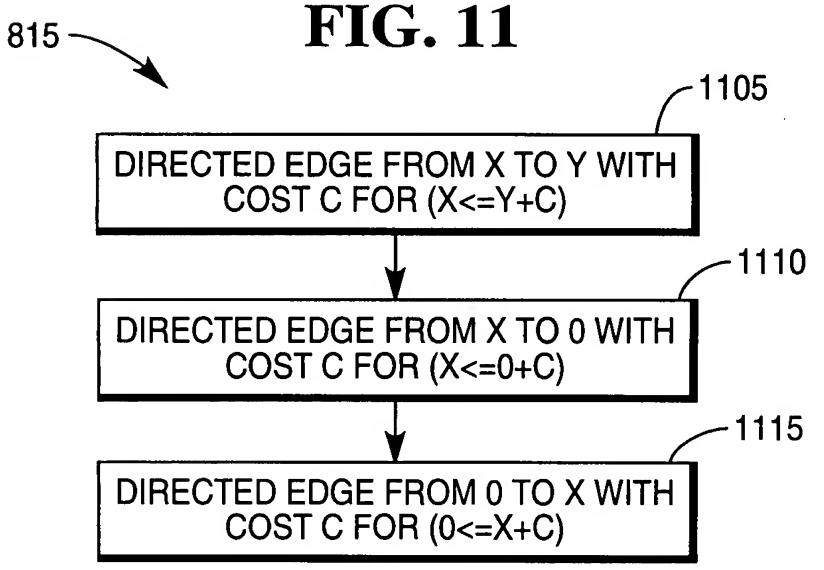
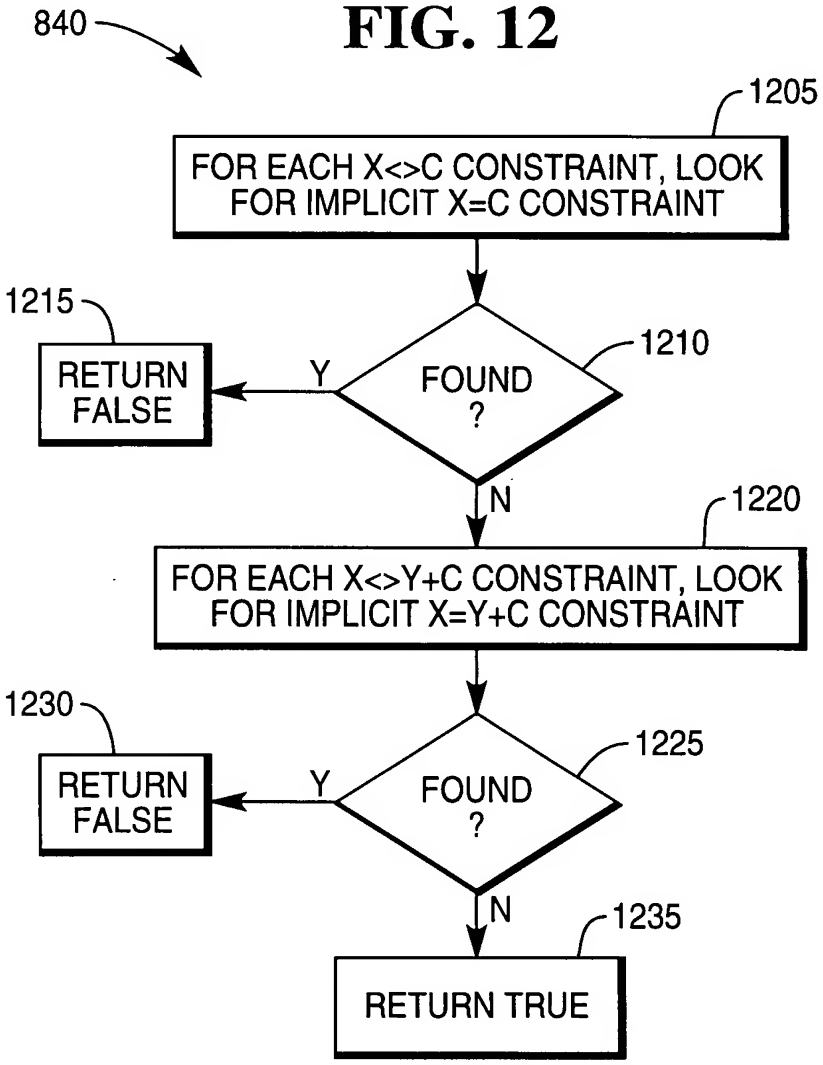

815
1105
DIRECTED EDGE FROM X TO Y WITH COST C FOR (X<=Y+C)
1110
DIRECTED EDGE FROM X TO 0 WITH COST C FOR (X<=0+C)
1115
DIRECTED EDGE FROM 0 TO X WITH COST C FOR (0<=X+C)

FIG. 11

FIG. 12


840
1205
FOR EACH X<>C CONSTRAINT, LOOK FOR IMPLICIT X=C CONSTRAINT
1215
RETURN FALSE
Y
FOUND ?
1210
N
1220
FOR EACH X<>Y+C CONSTRAINT, LOOK FOR IMPLICIT X=Y+C CONSTRAINT
1230
RETURN FALSE
Y
FOUND ?
1225
N
1235
RETURN TRUE

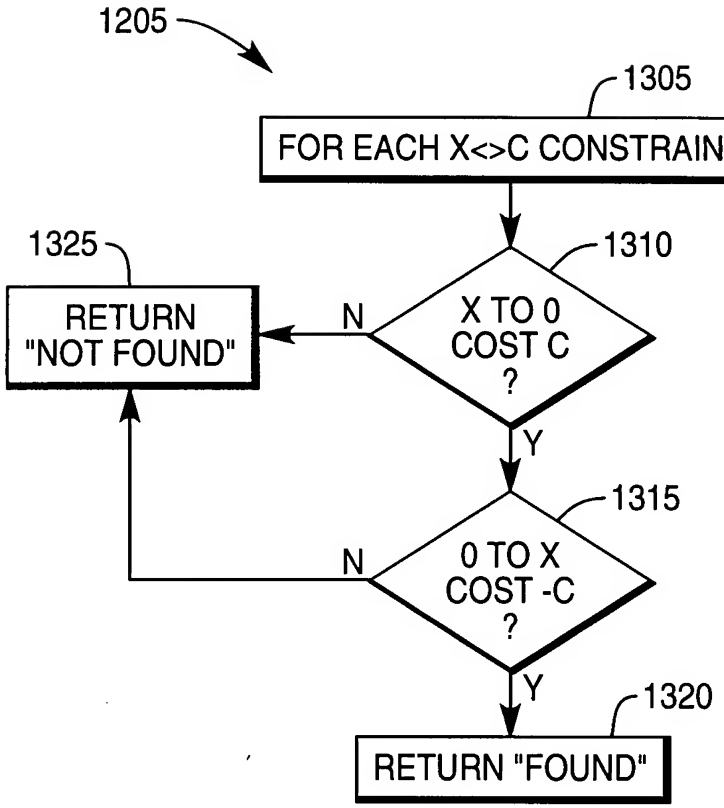

1205
1305
FOR EACH X<>C CONSTRAINT
1325
1310
RETURN "NOT FOUND"
N
X TO 0 COST C ?
Y
1315
N
0 TO X COST -C ?
Y
1320
RETURN "FOUND"

FIG. 13

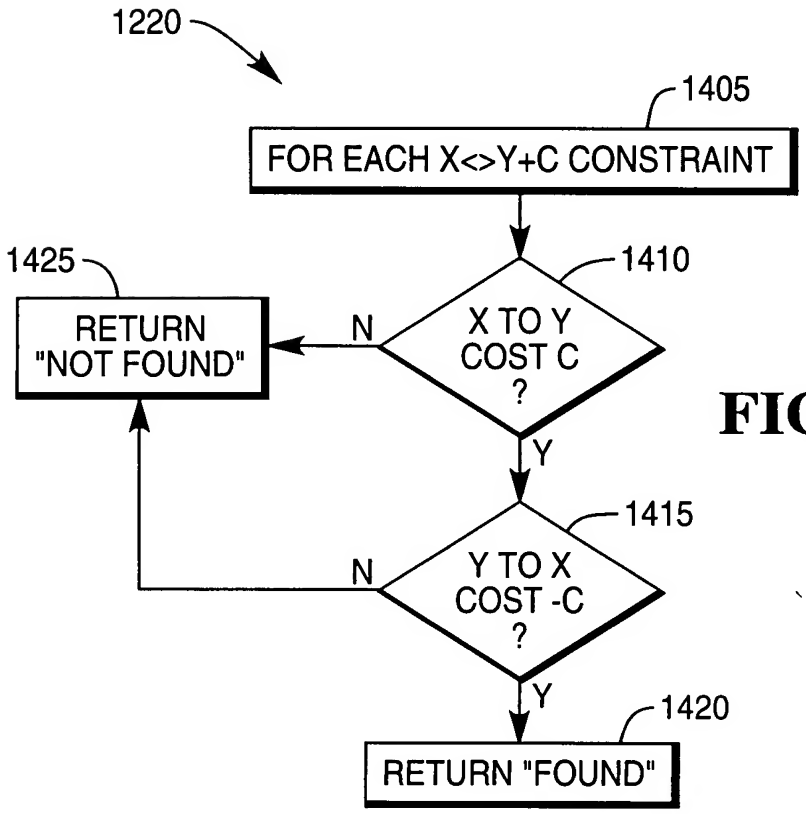

1220
1405
FOR EACH X<>Y+C CONSTRAINT
1425
1410
RETURN "NOT FOUND"
N
X TO Y COST C ?
Y
1415
N
Y TO X COST -C ?
Y
1420
RETURN "FOUND"

FIG. 14

FIG. 15

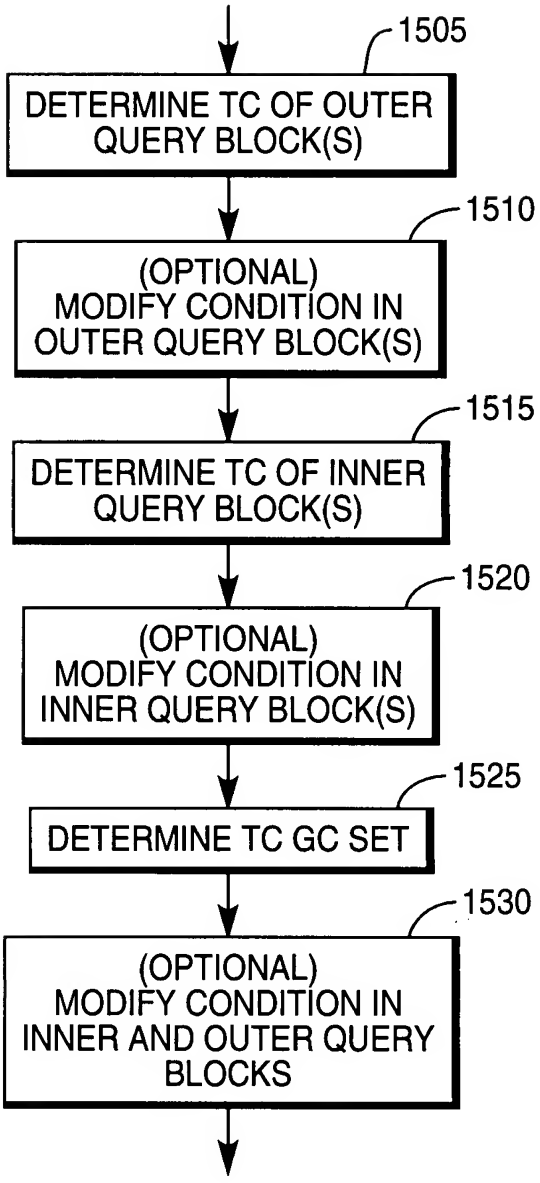
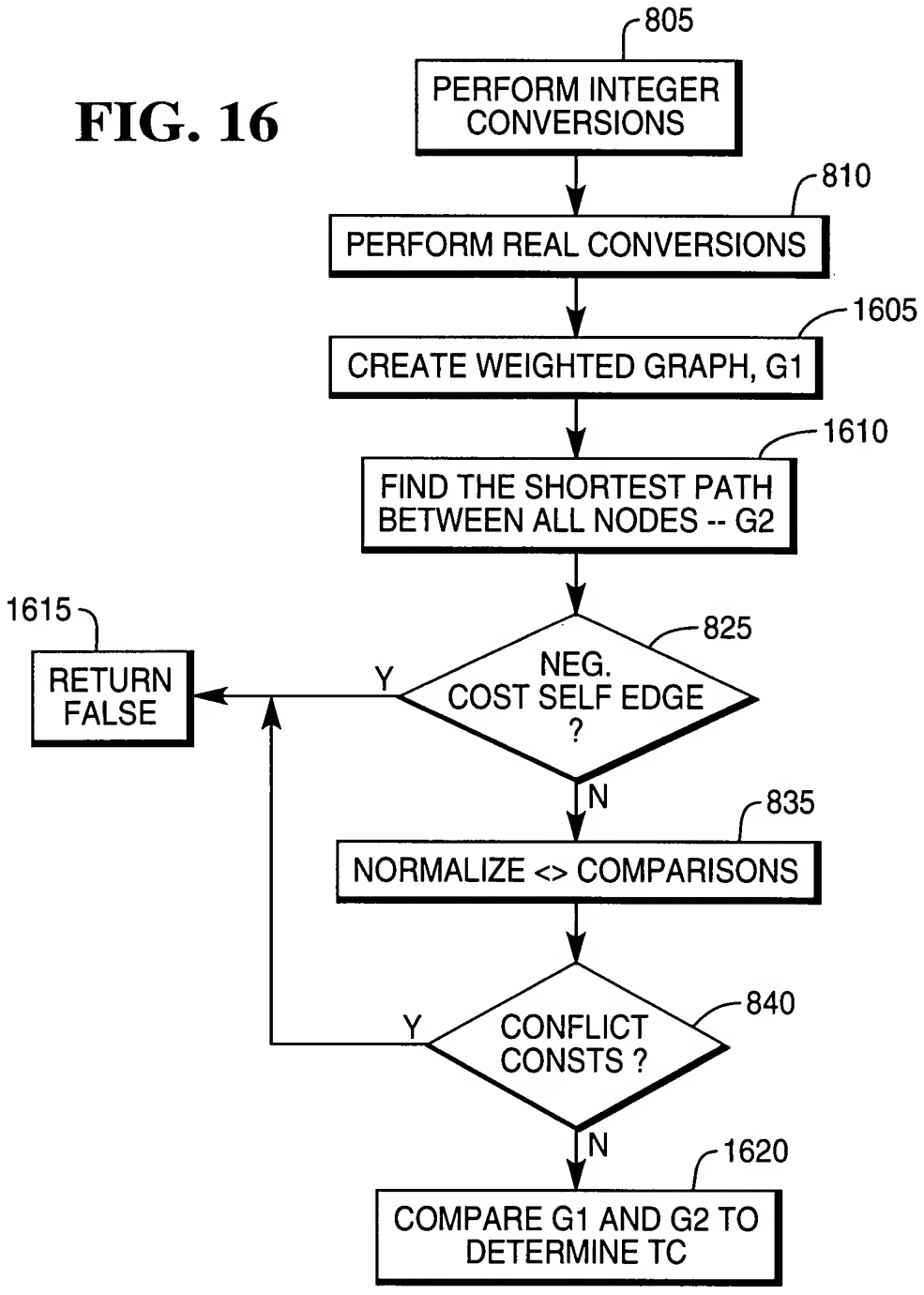

1505
DETERMINE TC OF OUTER QUERY BLOCK(S)
1510
(OPTIONAL) MODIFY CONDITION IN OUTER QUERY BLOCK(S)
1515
DETERMINE TC OF INNER QUERY BLOCK(S)
1520
(OPTIONAL) MODIFY CONDITION IN INNER QUERY BLOCK(S)
1525
DETERMINE TC GC SET
1530
(OPTIONAL) MODIFY CONDITION IN INNER AND OUTER QUERY BLOCKS

FIG. 16


805
PERFORM INTEGER CONVERSIONS
810
PERFORM REAL CONVERSIONS
1605
CREATE WEIGHTED GRAPH, G1
1610
FIND THE SHORTEST PATH BETWEEN ALL NODES -- G2
825
NEG. COST SELF EDGE ?
Y
1615
RETURN FALSE
N
835
NORMALIZE <> COMPARISONS
840
CONFLICT CONSTS ?
Y
N
1620
COMPARE G1 AND G2 TO DETERMINE TC

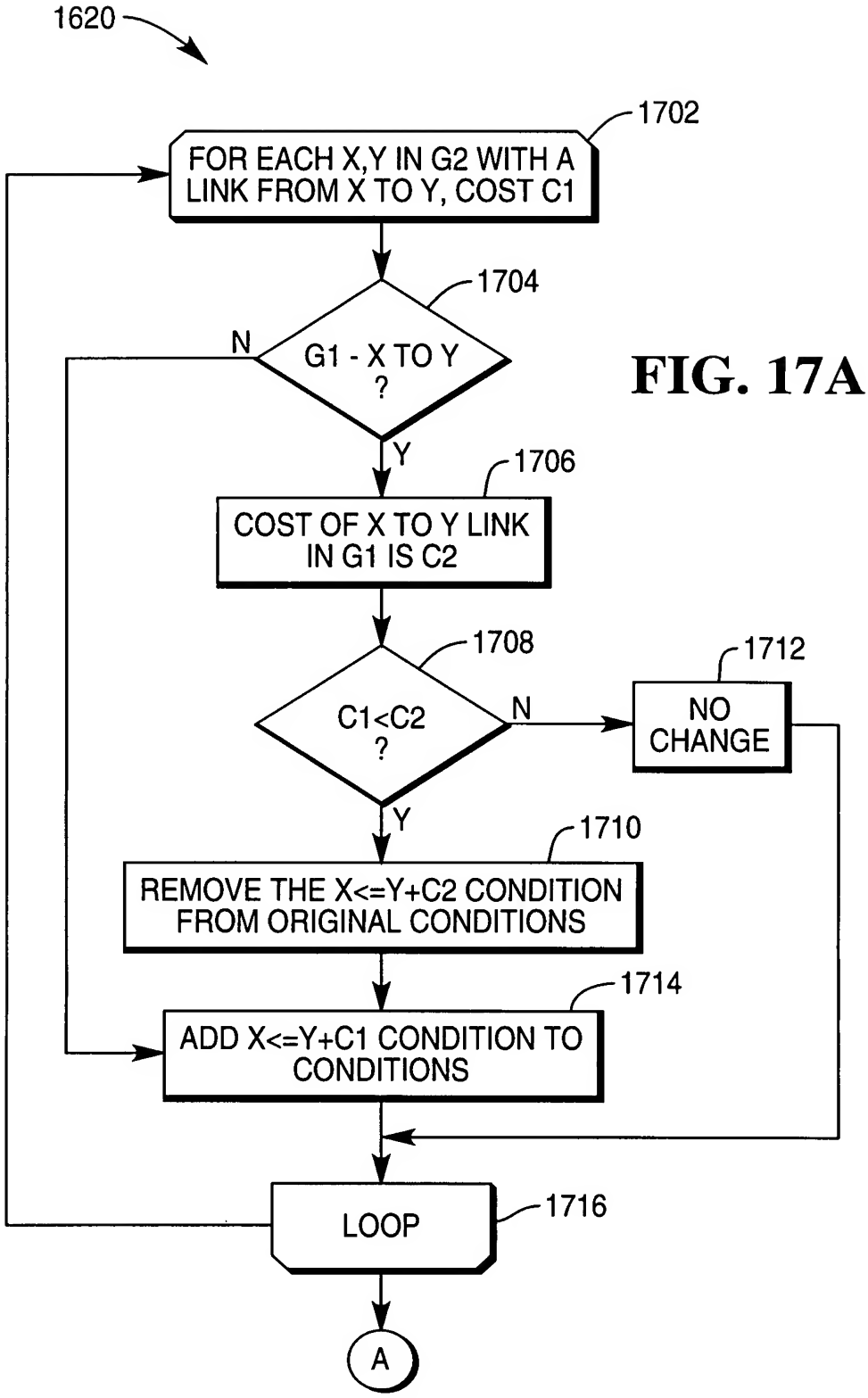

1620
1702
FOR EACH X,Y IN G2 WITH A LINK FROM X TO Y, COST C1
1704
G1 - X TO Y ?
N
Y
1706
COST OF X TO Y LINK IN G1 IS C2
1708
C1<C2 ?
N
1712
NO CHANGE
Y
1710
REMOVE THE X<=Y+C2 CONDITION FROM ORIGINAL CONDITIONS
1714
ADD X<=Y+C1 CONDITION TO CONDITIONS
LOOP
1716
A

FIG. 17A

FIG. 17B

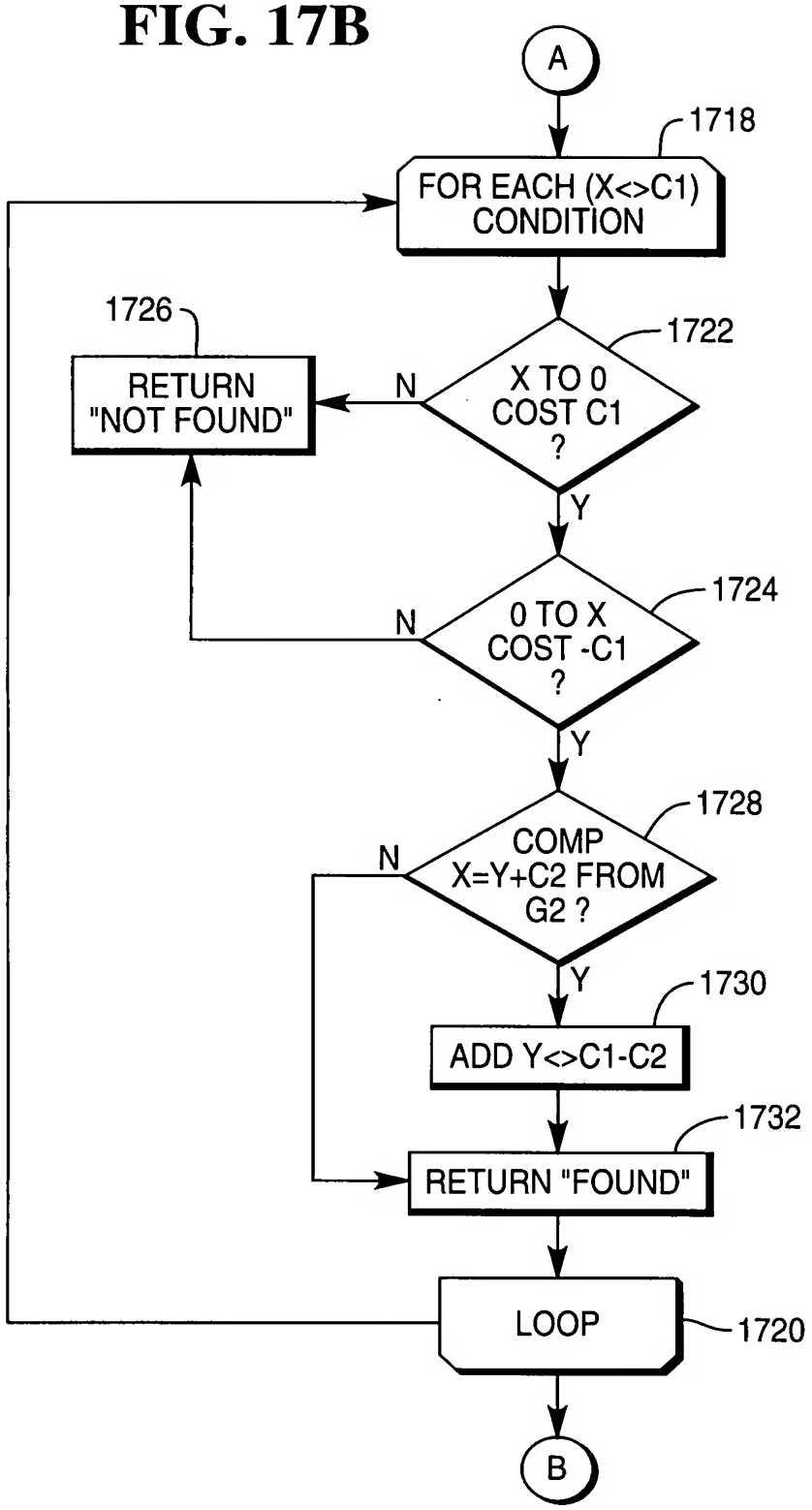
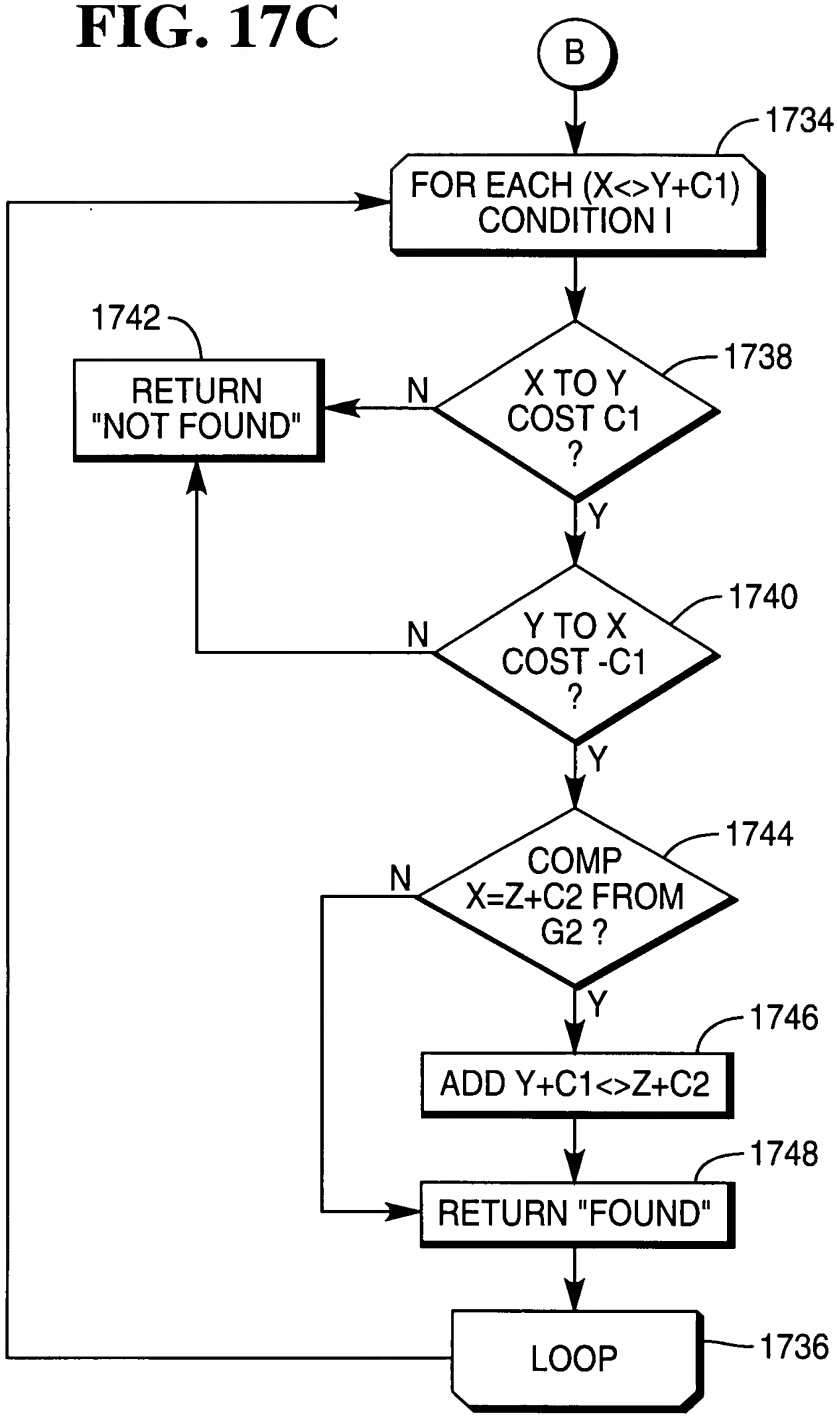

A
1718
FOR EACH (X<>C1) CONDITION
1726
RETURN "NOT FOUND"
N
1722
X TO 0 COST C1 ?
Y
N
1724
0 TO X COST -C1 ?
Y
N
1728
COMP X=Y+C2 FROM G2 ?
Y
1730
ADD Y<>C1-C2
1732
RETURN "FOUND"
LOOP
1720
B

FIG. 17C


B
1734
FOR EACH (X<>Y+C1) CONDITION I
1738
X TO Y COST C1 ?
N
1742
RETURN "NOT FOUND"
Y
1740
Y TO X COST -C1 ?
N
Y
1744
COMP X=Z+C2 FROM G2 ?
N
Y
1746
ADD Y+C1<>Z+C2
1748
RETURN "FOUND"
LOOP
1736

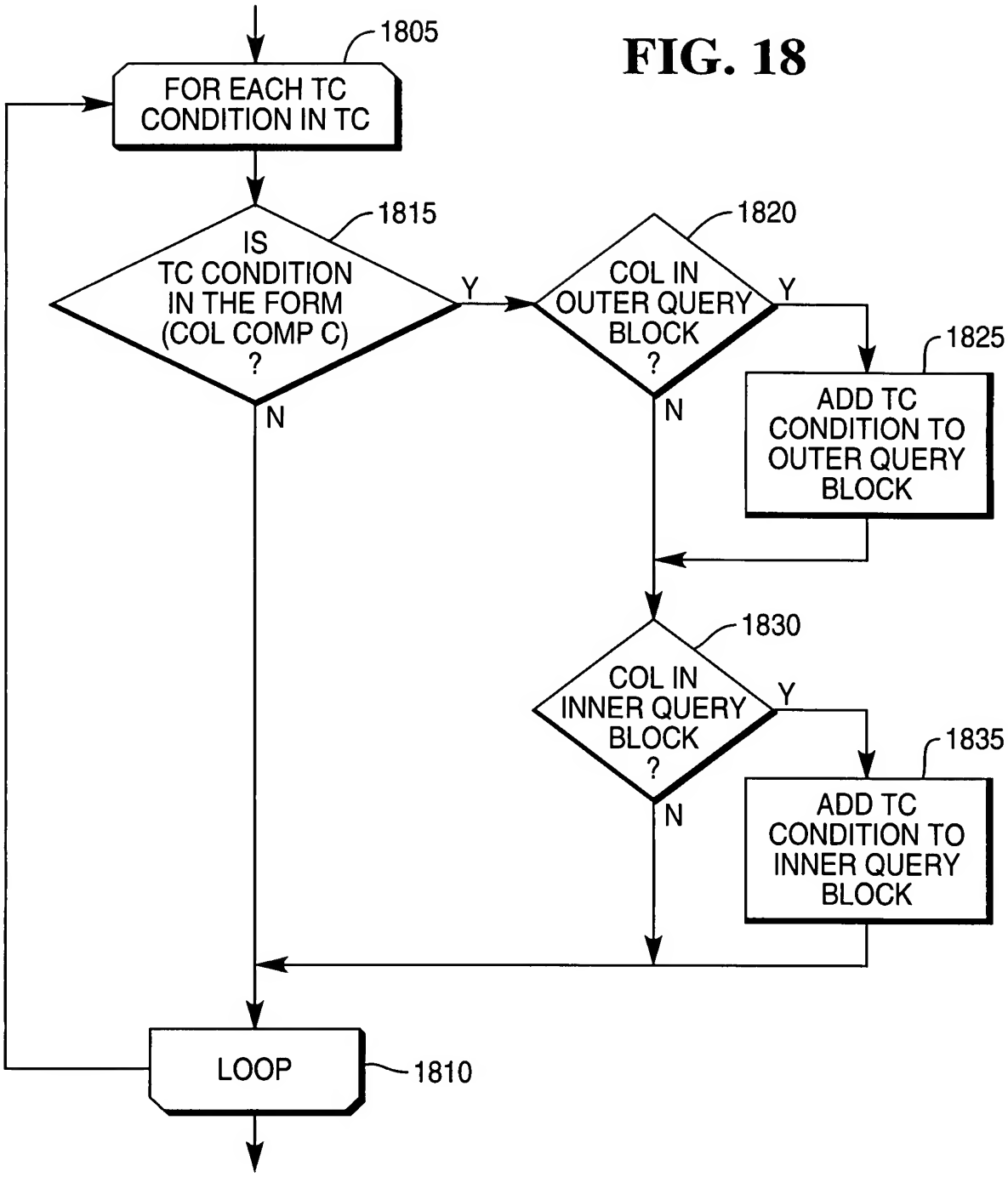

1805
FOR EACH TC CONDITION IN TC
1815
IS TC CONDITION IN THE FORM (COL COMP C) ?
Y
N
1820
COL IN OUTER QUERY BLOCK ?
Y
N
1825
ADD TC CONDITION TO OUTER QUERY BLOCK
1830
COL IN INNER QUERY BLOCK ?
Y
N
1835
ADD TC CONDITION TO INNER QUERY BLOCK
LOOP
1810

FIG. 18